

Science and Mathematics Education Centre

**The Effectiveness of Project-Based Mathematics in
the First Year of High School in Terms of
Learning Environment, Attitudes, Academic Efficacy and
Achievement**

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**This thesis is presented for the Degree of
Doctor of Philosophy
of
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DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgment has been made.

Human Ethics (For projects involving human participants/tissue, etc) The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC000262), Approval Number #SMEC–48-12

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ABSTRACT

This study of first-year high-school students in South Australia focussed on the effectiveness of using a project-based mathematics strategy in terms of classroom learning environment, attitude, academic efficacy and achievement. Associations between classroom learning environment and students' attitude, academic efficacy and achievement were also investigated. The study utilised a mixed-method approach which combined quantitative data from learning environment, attitude, academic efficacy and achievement measures with qualitative data from classroom observations and student and teacher interviews. Questionnaires were developed based on the What Is Happening In this Class? (WIHIC), the Attitude to Subject scale from the Test of Science Related Attitudes (TOSRA) and the Morgan-Jinks (MJSES) efficacy scale.

Over a period of six months, a sample involving 284 students in seven project-based classes followed a project-based learning curriculum, while three comparison classes followed a traditional mathematics curriculum. All research classes completed the questionnaires and were assessed using a local school-based achievement test at the beginning and conclusion of the study.

The structure of the learning environment and attitude/efficacy questionnaires was examined using principal axis factoring with varimax rotation and Kaiser normalization separately for each questionnaire and separately for pretest and posttest data. The criteria for the retention of any item were that it must have a factor loading of at least 0.40 with its own scale and less than 0.40 with every other scale in the same questionnaire. The application of these criteria led to the removal of four items and resulted in the a priori seven-scale structure of the WIHIC and the two-scale structure of the attitude/efficacy questionnaire replicating perfectly. The total proportion of variance accounted for by seven WIHIC scales was 63.37% for the pretest and 71.58 % for the posttest. For the two attitude/efficacy scales, the total proportion of variance was 70.82% for the pretest and 76.81% for the posttest. The internal consistency reliability of each WIHIC and attitude/efficacy scale was calculated separately for pretest and posttest data and separately for two units of analysis (the student and the class mean) using Cronbach's alpha coefficient. For the posttest, alpha coefficients for

the nine scales ranged from 0.87 to 0.97 with the student as the unit of analysis and from 0.83 to 0.98 with the class as the unit of analysis. When ANOVA was conducted for each learning environment scale, with class membership as the independent variable, it was found that nearly every WIHIC scale could differentiate significantly between the perceptions of students in different classrooms.

In considering the effectiveness of project-based mathematics and its differential effectiveness for males and females simultaneously, a two-way MANOVA with instructional method and sex as the independent variables and the set of ten learning environment, attitude/efficacy and achievement scales as the dependent variables was used. Because the multivariate test using Wilks' lambda criterion yielded statistically significant results for the whole set of dependent variables, the univariate ANOVA was interpreted separately for each individual learning environment, attitude/efficacy and achievement scale. The presence of a statistically significant instruction-by-sex interaction was used to signify that the project method was differentially effective for males and females. Also, effect sizes (Cohen's *d*) were used to portray the magnitudes of instructional differences in learning environment, attitude/efficacy and achievement scales in standard deviation units.

Significant instruction-by-sex interactions emerged for one WIHIC scale (Teacher Support) and both attitude/efficacy scales (but not for achievement). The interpretation of these interactions was that males benefitted more from the project-based method whereas females benefitted more from traditional methods in terms of perceived classroom environment and attitude/efficacy.

Overall, the project method was more effective than traditional methods in terms of (1) Teacher Support but only for males, (2) Attitude to Subject but only for males, and (3) Academic Efficacy with scores not significantly different either for different instructional methods or for different sexes, but males benefitting more from the project approach whereas females benefitted more from traditional methods. For achievement, the project method was less effective for both males and females.

Qualitative data generally supported the quantitative findings concerning the differential effectiveness of project-based mathematics for males and females.

Females questioned the purpose of project-based learning, found it confusing and difficult to make mathematical connections, and perceived it to be detrimental to their academic progress in the context of high academic expectations. On the other hand, females enjoyed this approach as a break from their traditional learning. Males reported that project-based learning was beneficial and that they enjoyed group work, involvement, challenge and choice of activity. Males enjoyed the practical tasks and connections to new learning and were less concerned about academic progress.

In the field of learning environment, this study is unique in terms of validating questionnaires based on the WIHIC and attitude and efficacy scales with first-year high-school students in South Australia. Moreover, because past studies into the effectiveness of project-based learning in mathematics in terms of learning environment, attitudes, academic efficacy and achievement are limited, this research potentially could contribute both to the field of learning environments and to our knowledge base about project-based mathematics. My findings concerning the differential effectiveness of project-based mathematics for males and females is noteworthy and hopefully will provide new insights into effective pedagogy in mathematics.

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TABLE OF CONTENTS

	Page
Abstract	iii
Acknowledgements	vi
Table of Contents	viii
List of Tables.....	xiii
List of Figures	xv
List of Acronyms	xvi

CHAPTER 1 INTRODUCTION

1.1	Introduction	1
1.2	Rationale of the study.....	2
1.3	Theoretical Framework	4
1.4	Research Questions and Intentions	7
1.5	Research Methods	8
1.6	Significance of the Study	9
1.7	Overview of the Thesis.....	10

CHAPTER 2 REVIEW OF LITERATURE

2.1	Introduction	12
2.2	Learning Environment Research	12
2.2.1	Background.....	13
2.2.2	Instruments for Assessing Classroom Environments	15
2.2.2.1	Learning Environment Inventory (LEI).....	17
2.2.2.2	Classroom Environment Scale (CES).....	17
2.2.2.3	Individualised Classroom Environment Questionnaire (ICEQ)	18
2.2.2.4	College and University Classroom Environment Inventory (CUCEI)	18

2.2.2.5	My Class Inventory (MCI).....	19
2.2.2.6	Questionnaire on Teacher Interaction (QTI).....	20
2.2.2.7	Science Laboratory Environment Inventory (SLEI).....	22
2.2.2.8	Constructivist Learning Environment Survey (CLES)	23
2.2.2.9	What Is Happening In this Class? (WIHIC) Questionnaire	25
2.2.2.10	Technology-Rich Outcomes-Focussed Learning Environment Inventory (TROFLEI)	25
2.2.2.11	Constructivist-Oriented Learning Environment Survey (COLES)	27
2.2.3	What Is Happening In this Class? (WIHIC).....	28
2.2.3.1	Background to the WIHIC	28
2.2.3.2	Validity and Application of the WIHIC in Past Studies ..	29
2.2.4	Past Research involving Learning Environments.....	33
2.2.4.1	Associations between Student Outcomes and Classroom Learning Environment	33
2.2.4.2	Evaluating Educational Innovations	38
2.2.4.3	Use of Qualitative Methods in Learning Environment Research	40
2.2.5	Summary Review of Learning Environment Literature.....	42
2.3	Student Attitudes	42
2.3.1	Defining Attitude.....	43
2.3.2	Validation and Use of the TOSRA.....	44
2.3.3	Academic Efficacy	46
2.4	Sex-Related Differences.....	49
2.5	Project-Based Learning	52
2.5.1	Project-Based Learning – Background	52
2.5.2	Features of Project-Based Learning	54
2.5.3	Past Research on the Effectiveness of Project-Based Learning	55
2.6	Summary	58

CHAPTER 3 RESEARCH METHODS

3.1	Introduction	60
3.2	Research Methods	60
3.3	Sample	61
3.4	Quantitative Data Collection	63
3.4.1	What Is Happening In this Class?	64
3.4.2	Assessing Student Attitudes	66
3.4.3	Assessing Student Achievement.....	68
3.4.4	Administration of the Survey	68
3.5	Qualitative Data Collection	69
3.5.1	Interviews with Students	70
3.5.2	Interviews with Staff	70
3.5.3	Classroom Observations	71
3.6	Data Analysis	71
3.6.1	Research Question 1	72
3.6.2	Research Question 2 and Research Question 3	73
3.6.3	Research Question 4	74
3.7	Ethical Issues	74
3.7.1	Information	75
3.7.2	Permission	75
3.7.3	Privacy and Confidentiality	75
3.7.4	Consideration and Acknowledgement.....	76
3.8	Summary	76

CHAPTER 4 DATA ANALYSES AND RESULTS

4.1	Introduction	79
4.2	Validity and Reliability of the WIHIC and Attitude/Efficacy Questionnaire	80
4.2.1	Factor Structure of the WIHIC	80
4.2.2	Factor Structure of the Attitude and Efficacy Scales	82
4.2.3	Internal Consistency Reliability	83
4.2.4	Discriminant Validity of WIHIC.....	84

4.2.5	Ability of the WIHIC to Differentiate between Classrooms	85
4.3	Differences between Instructional Methods and whether Instructional-Method Differences are Different for Males and Females	86
4.3.1	Instructional-Method and Sex Difference for each WIHIC, Attitude/Efficacy and Achievement Scale.....	87
4.3.2	Instructional-Method Differences in Learning Environment, Attitude and Achievement Scales.....	88
4.3.3	Sex Differences in Learning Environment, Attitude and Achievement Scales.....	89
4.3.4	Interaction between Instructional Method and Sex	90
4.4	Associations between Learning Environment, Attitude to Subject, Academic Efficacy and Achievement	93
4.4.1	Environment-attitude associations.....	94
4.4.2	Environment-efficacy associations.....	95
4.4.3	Environment-achievement associations	95
4.5	Using Qualitative Data to Explain Survey Findings	97
4.5.1	Theme 1: Pedagogy of Project-based Learning and the Role of the Teacher.....	99
4.5.2	Theme 2: Sex-related Differences in Project-based Learning.....	102
4.5.3	Theme 3: Attitude and Academic Efficacy in Project-based Learning	105
4.6	Concluding Remarks.....	107

CHAPTER 5 SUMMARY AND CONCLUSION

5.1	Introduction	111
5.2	Summary of the Thesis.....	111
5.3	Major Findings of the Study.....	113
5.3.1	Research Question 1	113
5.3.2	Research Question 2 and Research Question 3	115
5.3.2.1	Quantitative Analysis	115
5.3.2.2	Qualitative Analysis	117
5.3.3	Research Question 4.....	119

5.4	Significance and Implications	121
5.5	Limitations of the Study	122
5.6	Recommendations for Further Research	124
5.7	Summary and Final Comments	125

REFERENCES	126
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APPENDICES

Appendix A	Survey Instrument	155
Appendix B	Sample Questions from the Achievement Test	163
Appendix C	Sample of Interview Questions Students and Teachers	169
Appendix D	Observation Template	172
Appendix E	Participant Information Sheet	174
Appendix F	Student Consent Form	177
Appendix G	Ethics Approval	179

LIST OF TABLES

Table	Page
Table 2.1	Overview of Scales Contained in Some Classroom Environment Instruments 16
Table 2.2	Studies Involving the WIHIC in Investigating Associations Between Classroom Learning Environment and Student Outcomes 37
Table 3.1	Description of Whole Sample 62
Table 3.2	Scale Description and Sample Item for each WIHIC Scale 66
Table 3.3	Scale Description and Sample Item for the Attitude to Subject and Academic Efficacy Scales 67
Table 4.1	Factor Analysis Results for the WIHIC for Pretest and Posttest..... 81
Table 4.2	Factor Analysis Results for the Attitude to Subject and Efficacy Scales for Pretest and Posttest 83
Table 4.3	Internal Consistency Reliability (Cronbach Alpha Coefficient) for Two Units of analysis for the WIHIC and Attitude/Efficacy Scales 84
Table 4.4	Inter-correlations between WIHIC Scales for Pretest (Above the Diagonal) and Posttest (Below the Diagonal) 85
Table 4.5	Ability of the WIHIC to Differentiate Between Classrooms (ANOVA Results) for Pretest and Posttest 86
Table 4.6	Two-Way MANOVA/ANOVA Results (F and Eta^2) for Instructional-Method and Sex Differences for each WIHIC, Attitude/Efficacy and Achievement Scale..... 87
Table 4.7	Average Item Mean, Average Item Standard Deviation and Difference between Instructional Methods (Cohen's d Effect Size and ANOVA Results) for each Learning Environment, Attitude/Efficacy and Achievement Scale..... 89
Table 4.8	Average Item Mean, Average Item Standard Deviation and Sex Difference (Cohen's d Effect Size and ANOVA Results) for each Learning Environment, Attitude/Efficacy and Achievement Scales 90

Table 4.9	Average Item Mean, Average Item Standard Deviation and Sex Difference (Effect Size) for Two Instructional Methods for Learning Environment, Attitude/Efficacy and Achievement Scales	91
Table 4.10	Simple Correlation and Multiple Regression Analyses for Associations between Three Student Outcomes and Scales of the WIHIC	96

LIST OF FIGURES

Figure		Page
Figure 4.1	Statistically-Significant Interactions between Instructional Method and Sex	92

LIST OF ACRONYMS

Acronym	Meaning
LEI	Learning Environment Inventory
CES	Classroom Environment Scale
ICEQ	Individualised Classroom Environment Questionnaire
CUCEI	College and University Classroom Environment Inventory
MCI	My Class Inventory
QTI	Questionnaire on Teacher Interaction
SLEI	Science Laboratory Environment Inventory
CLES	Constructivist Learning Environment Survey
WIHC	What Is Happening In this Class?
COLES	Constructivist Oriented Learning Environment Survey
TROFLEI	Technology-Rich Outcomes-Focussed Learning Environment Inventory
TOSRA	Test of Science Related Attitudes
TOMRA	Test of Mathematics Related Attitudes
MJSES	Morgan Jinks Student Efficacy Scale
ToGRA	Test of Geography Related Attitudes
QOCRA	Questionnaire of Chemistry Related Attitudes
CCEI	Computerised Classroom Environment Inventory
CLEI	Chemistry Laboratory Environment Inventory
ANOVA	Analysis of Variance
MANOVA	Multivariate Analysis of Variance
SPSS	Statistical Package for Social Sciences
ACARA	Australian Curriculum and Assessment Reporting Authority
STEM	Science Technology Engineering Mathematics
PBL	Project-Based Learning

Chapter 1

INTRODUCTION

1.1 Introduction

Within current education circles and amongst policy makers, there is increasing importance given to engaging junior high school students meaningfully in mathematics in light of falling mathematics enrolments in the senior years of schooling (Ainley, Kos & Nicholas, 2008; Barrington & Brown, 2005; Collins, Kenway & McLeod, 2000; Kennedy, Lyons & Quinn, 2014). In addition, the latest Programme for International Student Assessment (PISA, 2015) shows that mathematics performance for Year 8 students declined significantly between 2012–2015 (Thomson, DeBortoli & Underwood, 2016). It is argued that students' choices are influenced by their attitudes towards and performance in mathematics, with these being shaped by students' experiences when learning mathematics in the middle years of schooling (Boaler & Greeno, 2000; Ma & Kishor, 1997; Nardi & Steward, 2003).

Classroom learning environments in high-school settings, particularly after transition from primary school to high school, often are perceived less favourably by students because of changes in curriculum, pedagogy, assessment strategies, social interactions and student relationships (Attard, 2010; Ferguson & Fraser, 1998). Explicit teaching of mathematical concepts using a procedural strategy, in isolation from problem solving and reasoning, is common in traditional high-school mathematics classes. Research indicates that low-level procedural mathematics during the first year of high school can lead to a negative learning experience (Attard, 2010).

Research over the last 45 years into learning environments has consistently revealed associations between the classroom learning environment and the learning outcomes of students (Aldridge & Fraser, 2008; Fraser 2012, 2014). My research is timely and significant in that it examined whether an innovative, constructivist-oriented approach using a project-based oriented strategy could lead to better classroom processes and student learning outcomes compared with a traditional approach.

The aim of this study was to examine the effectiveness of project-based mathematics in the first year of high school in terms of the learning environment and students' attitudes, academic efficacy and achievement. Associations between classroom learning environment and student outcomes were also investigated in this study.

A project-based mathematics learning strategy is defined as a research-based, open-ended and student-centred learning process, which is student-driven and teacher-facilitated (Bell, 2010). This instructional strategy can be effective in enhancing students' motivation and knowledge as they engage in higher-order thinking skills in order to achieve their tasks (Schwartz, Mennin, & Webb, 2001). A project-based mathematics learning strategy is focussed on engaging students using an instructional format that involves research, integrates theory and practice, applies skills and knowledge, and involves real-world projects which incorporate mathematical concepts (Bender, 2012; Savery, 2006). It features real-world projects using an engaging question, problem or task which is often ill-defined, integrated across several disciplines and connected with mathematical content in the context of working collaboratively with other students in a team (Barell, 2007, 2010; Baron, 2011; Grant, 2010).

This chapter provides a rationale of the study (Section 1.2), a theoretical framework (Section 1.3), a listing of the research questions (Section 1.4), a brief description of the research methods (Section 1.5), an explanation of the significance of the study (Section 1.6) and an overview of the structure of the thesis (Section 1.7).

1.2 Rationale of the Study

In a recent analysis of the Trends in International Mathematics and Science Study (TIMSS, 2015), it was reported that Australian achievement in mathematics for students in Year 8 has not changed from previous years dating back to 1995. Overall, there has not been any improvement in the average performance of Australian Year 8 students for 20 years (Thomson, Wernert, O'Grady & Rodrigues, 2016). This report reinforces an ongoing challenge for teachers to employ strategies which connect mathematics to relevant problems and activities. Studies from Australian mathematics classrooms continue to show trends which are characterised by a 'shallow teaching

syndrome' involving students in interacting with low-level mathematics, particularly in the area of algebra and reasoning (Dole, 2010; Stacey, 2003; Stacey & Vincent, 2009). The traditional approach to teaching mathematics continues to be primarily textbook oriented, focussed on teaching knowledge and skills in a range of mathematical strands. Students are taught a mathematical concept and engage with a range of routine problems in order to understand a concept. A high percentage of mathematical problems conducted in mathematics classes are reported as very close repetitions of previous problems conducted in primary school, which generally are of low procedural complexity and involve little mathematical reasoning. In addition, very few questions require students to make 'mathematical connections' and, where they do require making connections, the primary focus is on a solution (Lowrie & Logan, 2007).

Project-based mathematics as a strategy provides students with an opportunity to be engaged in their own learning and make relevant connections with mathematical concepts and the task in a constructivist-oriented learning environment (Ahmad, Tarmizi & Bayat, 2011). Self-regulated learning relies on learners having cognitive and motivational processes to steer their own learning outcomes (Velayutham, Aldridge & Fraser, 2011). The positive effects of project-based mathematics as a strategy in secondary education have been well documented in various studies (Megendollar, Maxwell & Belisimo, 2006).

Recent research suggests that sex-related differences in mathematics achievement are not as prevalent as in the past; however, there is a prevailing situation in which females express less confidence than males in their ability to do mathematics (Delgado & Prieto, 2004; Gijsbert & Geary, 2013; Nosek et al., 2009). Other negative attitudinal influences include females judging mathematics as being less useful (Fennema & Sherman, 1978). These findings were reinforced by the work of Ma and Cartwright (2003) who argued that females develop their attitudes towards mathematics and its utility independently of the school environment, context or educational climate.

A recent Australian position by the Chief Scientist calls for a Science, Technology, Engineering and Mathematics (STEM) focus in education to prepare a skilled and

dynamic workforce for the economic and social challenges of the future (Chief Scientist, 2014). In the latest international country comparison for STEM, Australia fairs adequately, but is behind a number of nations which have demonstrated strong performance in PISA (2015) and TIMMS (2015). The major finding is the importance of an educational focus on inquiry, reasoning, creativity and design in STEM curricula (ACOLA, 2013).

Research into the effectiveness of innovative teaching strategies in mathematics in the early years of high school is limited, particularly in terms of the differential effectiveness of teaching strategies for males and females. Given the body of research into male and female preferences in learning styles, collecting both quantitative and qualitative data about student perceptions of their learning environment, coupled with a deeper analysis of the relationship between learning environment and student outcomes, would assist in understanding the effectiveness of project-based activities in mathematics.

My study contributed to the fields of learning environments and students' attitudes to mathematics by using well-established instruments to assess learning environment, attitudes and academic efficacy. By examining students' perceptions of their learning environment in mathematics classes, and how these are associated with students' attitudes, academic efficacy and achievement, this study could provide valuable information for guiding future planning and further development of project-based mathematics. A detailed description of project-based mathematics is provided in Section 2.5.

1.3 Theoretical Framework

A major part of this study drew upon the field of learning environments in examining the effect of the classroom learning environment on the cognitive and affective outcomes of students in schools, as well as to provide criteria to evaluate the effectiveness of project-based mathematics instruction (Fraser, 1998a, 1998b, 2012; Fraser & Walberg, 1991; Chionh & Fraser, 2009). Because countries focus heavily on academic testing as a measure of educational outcomes against international benchmarks, Fraser (1998b) argued that a focus on academic achievement alone falls

short if not complemented by an evaluation of the classroom learning environment, teacher effectiveness and student progress. Past research has focussed on measuring the learning environment through the lens of the participant and considerable progress has been made in the use of learning environment tools which draw on participants' perceptions of the classroom to enable researchers to understand the learning process (Fraser, Aldridge & Adolphe, 2010; Chionh & Fraser, 2009; Ogbuehi & Fraser, 2007; Wolf & Fraser, 2008; Velayutham, Aldridge & Fraser, 2012).

The ideas of Lewin (1936) and his seminal work on field theory recognised the importance of the environmental space and its interaction with the affective dimensions of the person. Research on human environments established the environment as a powerful determinant of human behaviour. Murray (1938) introduced a needs–press model in which the behaviour of an individual is based on the needs of the individual in contrast to the press of the situation or environment. The work by Helbert Walberg in developing the widely-used Learning Environment Inventory (Walberg & Anderson, 1968) and Edison Trickett and Rudolf Moos's development of the Classroom Environment Scale (Moos & Trickett, 1974) prepared the way for learning environment questionnaires for specific purposes and diverse research programs across the world (Aldridge & Fraser, 2008; Fisher & Khine, 2006; Fraser, 1998, 2007). Fraser, Anderson and Walberg (1982) simplified the LEI to develop the My Class Inventory (MCI) which was targeted at primary-school and junior-high school students specifically. The work of Theo Wubbels in identifying the importance of the student and teacher interaction led to the development of the Questionnaire on Teacher Interaction (QTI) (Brekelmans & Wubbels, 2005; Fraser & Walberg, 2005; Levy & Wubbels, 1993).

In Australia, the student-centred classroom became a focus in education and led to extensive research, including the development of the Individualised Classroom Environment Survey (ICEQ; Fraser, 1990; Fraser & Butts, 1982). This questionnaire differed from the LEI and CES which focus on a teacher-centred classroom. Subsequently, Taylor, Fraser and Fisher (1997) extended this research with the Constructivist Learning Environment Survey (CLES) which enabled teachers to reflect on the survey data and their teaching practice in order to make adjustments to their

lessons and make improvements to the learning environment (Aldridge, Fraser & Sebela, 2004).

The WIHIC drew on several previous learning environment questionnaires and it is the most commonly-used questionnaire in this field. Developed by Fraser, Fisher and McRobbie (1996) as a 90-item nine-scale questionnaire, it was refined to a 56-item seven-scale questionnaire (Aldridge, Fraser & Huang, 1999). It assesses numerous dimensions of the learning environment and was used as the primary questionnaire in my study. This questionnaire's seven scales are Teacher Support, Involvement, Student Cohesiveness, Task Orientation, Cooperation, Investigation and Equity.

My study also focussed on student attitudes and academic efficacy. Attitude can be considered under three components, namely, cognitive, affective and behavioural (Reid, 2006). Attitude can be defined as "the feelings that a person has about an object, based on their beliefs about that object" (Kind, Jones & Barmby, 2007, p. 873).

This definition allows an attitude to a school subject to be measured in terms of students' cognitive and emotional opinions about aspects of that subject, which include opinions about the classroom environment, the teacher, the curriculum and the activities in the classroom (Ma & Kishor, 1997; Tapia & Marsh, 2004). The Test of Science Related Attitudes (TOSRA; Fraser, 1981) was developed specifically to measure the progress of high-school students in developing attitudes in science. Using the seven-scale TOSRA, it is possible to produce a score on each scale and thereby create a profile of an individual or class.

The Morgan-Jinks student efficacy scale (MJSES) was designed to gain information regarding students' belief in their academic success (Morgan & Jinks, 1994, 1999). Social theorists suggest that self-efficacy, or belief and confidence in completing a task, is important and can influence certain behaviours towards learning. It is argued that high levels of self-efficacy can contribute to greater academic success (Bandura, 1982, 1989a, 1989b). In my study, scales of the WIHIC were used in conjunction with one scale from the TOSRA, namely, Attitude to Subject, and the Morgan-Jinks student efficacy scale (MJSES). A detailed description of learning environment, attitude and efficacy instruments is provided in Section 2.2.2, 2.3.2 and 2.3.3.

1.4 Research Questions and Intentions

The intentions of this study were to modify and validate a questionnaire based on seven scales of the WIHIC, one attitude scale from the TOSRA and the Morgan-Jinks student efficacy scale with a sample of first-year high-school students from Adelaide, South Australia, as well as to evaluate different instructional methods (project-based learning or traditional learning) of first-year high-school students' perceptions of their learning environment and their attitude, academic efficacy and achievement. This study also investigated whether any differences existing between instructional methods were similar or different for male and female students, and whether there were any associations between the learning environment and student outcomes. Specific research questions are listed below.

I examined the validity and reliability of the questionnaire for gathering data on students' perceptions of their classroom learning environment, attitude and academic efficacy in mathematics.

Research Question 1:

Is it possible to modify and validate a questionnaire based on the WIHIC and attitude and efficacy scales for use with first-year high-school students in Adelaide, South Australia?

To examine the effectiveness of project-based mathematics in terms of students' perceptions of their learning environment, attitudes, academic efficacy and achievement, the following research question was delineated.

Research Question 2:

Is project-based mathematics effective for first-year high-school students' in terms of:

- a. learning environment
- b. attitudes
- c. academic efficacy
- d. achievement?

To investigate whether project-based mathematics is differentially effective for males and females in terms of their learning environment, attitudes, academic efficacy and achievement, the third question was delineated:

Research Question 3:

Is project-based mathematics differentially effective for males and females in terms of:

- a. learning environment
- b. attitudes
- c. academic efficacy
- d. achievement?

In order to establish whether any relationships exists between students' perceptions of their classroom learning environment and student outcomes, the fourth research question was delineated:

Research Question 4:

Are there associations between the learning environment and students':

- a. attitudes
- b. academic efficacy
- c. achievement?

1.5 Research Methods

In order to answer the four research questions, an explanatory mixed-method design was utilised with multiple forms of data collected, including survey data, achievement tests, classroom observations and semi-structured interviews. The study involved data collection at the beginning of the project-based strategy and at the conclusion of the study. The sample included two groups, namely, students in mathematics classes involved in the project-based strategy (in which mathematical concepts are taught through application of mathematical skills and understanding) and students in

mathematics classes following a traditional curriculum strategy (which involves the explicit teaching of mathematical concepts in terms of skills and understanding). Students in first-year high school were surveyed at the beginning of the year following transition (from primary school to high school). These students transitioned from 32 different primary schools to the research school. Seven project-based classes and three non-project-based classes were established in this high school in South Australia.

Achievement was measured with a multiple-choice mathematics test which was administered at the beginning and end of the study. The questionnaire and achievement scores were analysed using relevant statistical measures and complemented by an analysis of explanatory data collected in the qualitative section of this study. Chapter 3 provides a detailed explanation of the research methods used.

1.6 Significance of the Study

This study contributed to the field of learning environments. First, the study is unique within this field in terms of validating a questionnaire based on the WIHIC and Attitude and Efficacy scales with first-year high-school students in South Australia, thereby contributing to the ever-expanding body of this research, especially involving use of the WIHIC. Second, the use of learning environment criteria in evaluating the effectiveness of project-based learning in mathematics is limited, particularly in the early stages of high school. Investigation of the differential effectiveness of project-based mathematics for males and females in terms of their perceptions of their learning environment is novel and could offer insights into the differentiated learning preferences of males and females.

Some practical implications flow from this study. It is likely that my results will provide new information about students in their first year of high school, especially how a new teaching strategy can impact the learning environment, attitude to mathematics, academic efficacy and achievement. Because schools are constantly looking to improve student engagement and learning outcomes, teachers question whether using innovative new strategies can have a different impact on males and females.

This research is methodologically distinctive because it combined multiple research methods (quantitative and qualitative) to provide a legitimate inquiry approach as recommended by Brewer and Hunter (1989) and Creswell (2008).

1.7 Overview of the Thesis

Chapter 1 provided an introduction including background information into the current Australian educational context which motivated this study. It contextualised the study within the field of learning environments and provided a theoretical framework. The research questions were stated, research methods were explained and a brief exploration of the significance of the study was presented.

Chapter 2 provides a review of literature related to this study. It reviews the field of learning environments, including background information, past research and learning environment instruments. Research on student attitudes and efficacy is covered particularly as it is associated with learning environment research. This chapter also covers studies of sex-related differences, including current and past research into differences between males and females as they apply to mathematics and science education and specifically to learning environment and student outcomes. An overview of project-based learning, which includes features of project-based learning and past research on the effectiveness of this strategy in mathematics, is also included.

Chapter 3 details information about the research methodology utilised in my study with particular emphasis on the development of the questionnaire using the WIHIC, an attitude scale from the TOSRA and the Morgan-Jinks efficacy scale. It describes the statistical analysis needed to ensure that the research instruments were valid and reliable in the context of this study. The sample in my study is explained further. The quantitative and qualitative data-collection methods are clarified and the data-analysis methods are justified and explained. Ethical issues are also covered and explored.

Chapter 4 consists of a detailed description of the data analyses and findings based on the quantitative data for the four research questions. The first research question focussing on the validity and reliability of the WIHIC and attitude scales is answered in Section 4.2. The second and third research questions are considered together and

focus on differences between instructional methods in effectiveness and whether the project-based method is differentially effective for males and females (Section 4.3). The fourth research question, concerning associations between the learning environment and the student outcomes of attitudes, academic efficacy and achievement, is the focus of Section 4.4. This chapter also contains a detailed description of the data analyses and findings based on qualitative data in relation to three of the research questions.

Chapter 5 contains an in-depth discussion of the results of my study, as well as their significance, limitations and educational implications. It also provides recommendations for further research and concluding remarks.

Chapter 2

REVIEW OF LITERATURE

2.1 Introduction

The review of the literature is designed to examine previous and current research related to my study and to consider it from a historical perspective. It provides background information about research pertaining to learning environments, attitude to subject, academic efficacy, sex-related differences and project-based learning.

This chapter begins with an in-depth focus on the field of learning environments in Section 2.2 and includes a detailed review of instruments for assessing learning environments (Section 2.2.1). Because my study used the seven scales of the What Is Happening In this Class? (WIHIC) questionnaire (Fraser, Fisher & McRobbie, 1996), a review of the research related to the validation of the WIHIC is covered in Section 2.2.3. Related research in terms of learning environments is covered in Section 2.2.4.

A review of research on attitudes, which were assessed in this study using a modified scale from the Test of Science Related Attitudes (TOSRA) questionnaire (Fraser, 1981a), is covered in Section 2.3. This includes research related to attitudes (Section 2.3.1) and the validation of the TOSRA and related research in Section 2.3.2. A review of academic efficacy and studies using the Morgan-Jinks student efficacy scale (Jinks & Morgan, 1999) is discussed in Section 2.3.4. Sex-related differences are covered in Section 2.4 and, finally, project-based mathematics is covered in Section 2.5 with a discussion of a range of similar studies in Section 2.5.1.

2.2 Learning Environment Research

The primary focus of this study was the effectiveness of project-based learning in mathematics in terms of students' view of their learning environment. To understand the context of this study, a detailed review of the literature is provided for this field.

2.2.1 Background

The effect of the learning environment on the cognitive and affective outcomes of students is well documented as being at the heart of this field of study (Fraser, 1998a, 2007, 2012; Fraser & Walberg, 1991; Chionh & Fraser, 2009). Students and teachers share perceptions of their classroom learning environment which can contribute to a common understanding of what is beneficial in optimising learning. “Students are at a good vantage point to make judgements about classrooms because they have encountered many different learning environments” (Fraser, 2012, p. 1192). The definition of learning environment has incorporated the overall climate, culture or atmosphere of where learning occurs, including the physical elements of the learning space (Fraser, 1998b).

Modern research on learning environments is underpinned by the ideas of Lewin (1936) and his fundamental work on field theory. This theory highlights that interactions between the environment and the characteristics of the individual are powerful factors which affect human behaviour. Lewin developed a formula which emphasised that behaviour results from the interaction of the person and the environment. Murray (1938) expanded on Lewin’s work when he introduced the concept of *alpha press* to describe an outside observer’s perspective of the environment and *beta press* from the participant’s perspective. He referred to the term *press* as forces that either support or hinder an individual’s perceived needs. Stern (1970), drawing on Murray’s work, developed a theory of person–environment congruence in which a combination of personal needs and environmental press could affect student outcomes. Person–environment fit research, was influential in the emerging view that perceptions of learning environment, could be aligned with traditional qualitative research methods using observations and notes by an external researcher (Bell & Aldridge, 2014). The emergence of the idea of teachers and students having shared perceptions of the learning environment was an important point in the history of learning environments.

Psychosocial learning environment is considered as a factor in a multifactor psychological model of educational productivity (Walberg, 1981). In essence, this

theory holds that the quality of learning depends on student age, ability and motivation, the quality and quantity of instruction and the psychosocial influences of home life, the classroom setting, friendship group and, more significantly today, the impact of social media. Considering all these factors, Fraser (2012, p. 1219) stated that “any factor at a zero-point will result in zero learning”. Significant findings in research across the world involving the dimensions of learning environment and the quality of learning has shown strong correlations between learning and these dimensions and concluded that what happens in a school and classroom is a strong predictor of student outcomes.

The work by Helbert Walberg in developing the Learning Environment Inventory (LEI) (Walberg & Anderson, 1968) provided the foundation for further research on learning environments. Rudolf Moos, working closely with Edison Trickett, advanced the development of social climate scales using psychiatric hospitals and correctional institutions. Moos and Trickett’s work led to the development of the Classroom Environment Scale (CES, Moos & Trickett, 1974; Trickett & Moos, 1973). Moos’ research prepared the foundation for the development of many learning environment instruments and for diverse research programs across the world (Aldridge & Fraser, 2008; Fisher & Khine, 2006; Fraser, 1998a, 2007, 2014).

In an environment where countries focus heavily on academic testing to measure educational outcomes against international benchmarks, Fraser (1998b) argued that a focus on academic achievement falls short without an evaluation of the classroom learning environment, teacher effectiveness and student progress. Whereas past research focussed on measuring the learning environment through the lens of an outside observer, considerable progress was made when learning environment tools were used to draw on the participant’s perceptions of the classroom and to enable researchers to draw meaning from the learning process (Fraser, 1986, 1994, 1998b; Fraser & Walberg, 1991; Aldridge, Fraser & Huang, 1999).

As research advanced rapidly over the last 50 years and more studies across different continents were completed, the field of learning environment gained acceptance and credibility across the world and learning environment was established as an important

field of study related to the conceptualisation, evaluation and investigation into student perceptions of psychological and social factors in the learning environment (Fraser, 2012; Bell & Aldridge, 2014).

2.2.2 *Instruments for Assessing Learning Environments*

For 50 years, the effectiveness and importance of specific instruments to measure classroom climate and assess students' perceptions of a range of dimensions of learning environment have established its place in educational research (Fraser, 2007, 2012). Instruments assessing learning environment measure specific scales based on Moos's (1979) scheme classifying the dimensions of human environments (Fraser, 1998a). Three categories were considered by Moos to describe human environments. The first category involving Relationship dimensions describes both context and depth of personal relationships and assesses the extent to which participants support and are immersed in all aspects of the learning environment. Personal Development dimensions are the second category and assess the extent to which personal growth and enrichment occur. The third category involves System Maintenance and Change dimensions which describe the extent to which the learning environment is considered safe and orderly, where expectations of participants are clear and discipline is maintained with an openness to improvement. Many new instruments have been developed to assess different dimensions of the classroom learning environment based on Moos' (1979) three basic categories of human environments (see Sections 2.2.2.1 to 2.2.2.11 and 2.2.3).

Table 2.1 provides a summary of 11 significant classroom environment instruments developed over time, the level for which the instrument is best suited (primary, secondary, higher education), the specific scales classified using Moos's categories namely, relationship dimension, personal development dimension and system maintenance and change dimensions (Moos, 1974).

Table 2.1 Overview of Scales Contained in Some Classroom Environment Instruments (LEI, CES, ICEQ, CUCEI, MCI, QTI, SLEI, CLES, WIHIC, TROFLEI and COLES)

Instrument	Level	Items per Scale	Scales Classified According to Moos's Scheme		
			Relationship Dimension	Personal Development Dimensions	System Maintenance and Change Dimensions
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness Friction Favouritism Cliquesness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material environment Goal Direction Disorganisation Democracy
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher support	Task orientation Competition	Order and organisation Rule clarity Teacher control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalisation Participation	Independence Investigation	Differentiation
College and University Classroom Environment Inventory (CUCEI)	Higher Education	10	Personalisation Involvement Student cohesiveness Satisfaction	Task orientation	Innovation Individualisation
My Class Inventory (MCI)	Elementary	6-9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
Questionnaire on Teacher Interaction (QTI)	Secondary/Primary	8-10	Leadership Helpful/Friendly Understanding Student responsibility and freedom Uncertain Dissatisfied Admonishing Strict		
Science Laboratory Environment Survey (SLEI)	Upper Secondary/ Higher Education	7	Student cohesiveness	Open-Endedness Integration	Rule clarity Material environment
Constructivist Learning Environment Survey (CLES)	Secondary	7	Personal relevance Uncertainty	Critical voice Shared control	Student negotiation
What Is Happening In this Class (WIHIC)	Secondary	8	Student cohesiveness Teacher support Involvement	Investigation Task orientation Cooperation	Equity
Technology-Rich Outcomes-Focussed Learning Environment Inventory (TROFLEI)	Secondary	10	Student cohesiveness Teacher support Involvement Young adult ethos	Investigation Task orientation Cooperation	Equity Differentiation Computer usage
Constructivist-Oriented Learning Environment Survey (COLES)	Secondary	11	Student cohesiveness Teacher support Involvement Young adult ethos Personal relevance	Task orientation Cooperation	Equity

*Adapted from Fraser (2012) with permission

2.2.2.1 Learning Environment Inventory (LEI)

Historically, four instruments are well known for having established the foundation for this field of study. Towards the end of the 1960s, and in conjunction with the evaluation of the Harvard Project Physics (Fraser et al., 1982; Walberg & Anderson, 1968), research involved the initial development of the Learning Environment Inventory (LEI). This questionnaire for secondary students measures the social climate of classrooms with 15 different scales involving Cohesiveness, Friction, Favouritism, Cliqueness, Satisfaction, Apathy, Speed, Difficulty, Competitiveness, Diversity, Formality, Material Environment, Goal Direction, Disorganisation, Democracy, with seven statements in each scale for a total of 105 items. Respondents complete each statement by responding to a 4-point Likert scale consisting of Strongly Agree, Agree, Disagree, Strongly Disagree (Fraser, Anderson & Walberg, 1982; Walberg & Anderson, 1968). The LEI has two distinct uses, namely, the assessment of perceptions of individual students and class perceptions of the learning environment.

2.2.2.2 Classroom Environment Scale (CES)

The Classroom Environment Scale (CES) was developed around the same time as the LEI by Moos and Trickett (1974). Initial research in hospitals, prisons and educational institutions focussed on perceptual measures describing human environments and led to the evolution of a questionnaire for secondary students. The CES's primary focus is either students' or teachers' perceptions of the preferred classroom environment in addition to the actual classroom environment (Fisher & Fraser, 1983). The final published questionnaire consisted of 9 different scales, namely, Involvement, Affiliation, Teacher Support, Task Orientation, Competition, Order and Organisation, Rule Clarity, Teacher Control and Innovation, with 10 statements each for a total of 90 items, and uses a True–False response format for each item (Moos & Trickett, 1974; Trickett & Moos, 1973). Moos and Trickett (1974) reported that the CES revealed significant relationships between the scales of classroom learning environment and student satisfaction and moods.

2.2.2.3 Individualised Classroom Environment Questionnaire (ICEQ)

Because of research in the area of individualised open and inquiry-based education, A. John Rentoul and Barry Fraser (1979) developed the Individualised Classroom Environment Questionnaire (ICEQ). In Australia, the student-centred classroom became a focus in education and led to extensive research and the development of the ICEQ (Fraser, 1990; Fraser & Butts, 1982). This questionnaire differed from the LEI and CES and focussed on teacher-centred classrooms. The ICEQ measures important dimensions which differentiate the individualised classroom from the conventional classroom (Fraser, 1980). Interviews were conducted with teachers and high-school students and their reactions recorded. In addition, their feedback was sought on draft versions measuring both a preferred and actual perspective of the learning environment. This resulted in a final published questionnaire with 5 scales, namely, Personalisation, Participation, Independence, Investigation and Differentiation, with 10 items for each scale for a total of 50 items. A five-point frequency scale consisting of Almost Never, Seldom, Sometimes, Often and Very Often was used to respond to each item. Reversal of the scoring direction with items in the ICEQ facilitated respondent authenticity (Fraser, 1990; Fraser & Butts, 1982).

2.2.2.4 College and University Classroom Environment Inventory (CUCEI)

Research in classroom learning environment at the secondary-school and primary-school level was expanded to include classrooms in higher education, but this was surprisingly minimal. The College and University Classroom Environment Inventory (CUCEI) was developed by Barry Fraser and David Treagust for small classes of up to 30 students (Fraser & Treagust, 1986). The final version of the CUCEI assesses students' and teachers' perceptions of seven psychosocial dimensions of an actual and preferred classroom environment which include the scales of Personalisation, Involvement, Student Cohesiveness, Satisfaction, Task Orientation, Innovation and Individualisation, with seven items in each scale. Each item has responses on a four-point Likert scale of Strongly Agree, Agree, Disagree, Strongly Disagree. Again the scoring direction is reversed for approximately half the items.

Hasan and Fraser (2015) investigated the effectiveness of an innovative teaching strategy based on activity-based teaching in mathematics. A sample of 84 students from eight classes in Higher Colleges of Technology in the United Arab Emirates was used to investigate the learning environment using four scales of the CUCEI, namely, Involvement, Task Orientation, Personalisation and Individualisation, with Satisfaction also included and translated into Arabic. The effectiveness of this innovative strategy was supported by the magnitude and statistical significance of pretest–posttest changes in scale scores, with qualitative data embellishing the quantitative findings. The study was significant as one of the first studies of learning environment conducted in the United Arab Emirates using a modified CUCEI. The CUCEI was translated into Arabic and validated.

2.2.2.5 My Class Inventory (MCI)

Fraser, Anderson and Walberg (1982) simplified the LEI to develop the My Class Inventory (MCI) for use among students of ages 8 to 12 years. Subsequently, Fisher and Fraser (1981) simplified the original version of the MCI into a 38-item version and later a short 25-item version was further evolved by Fraser and O'Brien (1985). The MCI differs from the LEI in terms of simplicity, accuracy and readability. It only contains five of the original LEI's 15 scales to avoid fatigue with young people, the MCI's wording was modified to enhance readability, the four-point response format was changed to a two-point Yes–No format and students answered on the questionnaire rather than on a separate response sheet to minimise errors in transferring responses. The MCI contains five scales (Cohesiveness, Friction, Satisfaction, Difficulty and Competitiveness) and utilises between six to nine items. The MCI was modified by Goh and Fraser (1998) to involve a three-point response format (Seldom, Sometimes, Most of the Time) and they also added a Task Orientation scale for research with primary mathematics students in Singapore.

Research in Brunei Darussalam by Majeed, Fraser and Aldridge (2002) validated a modified form of the MCI which assessed cohesiveness, difficulty and competition. This study involving 1565 lower-secondary mathematics students in 81 classes in 15 government schools established a satisfactory factor structure and sound reliability for

the refined three-scale structure. The study on learning environment perceptions revealed significant sex-related differences and associations between learning environment and student satisfaction.

Mink and Fraser (2005) evaluated a K–5 mathematics program which integrates children’s literature using the MCI. The MCI, along with attitude scales and qualitative methods, was used with 120 mathematics students in grade 5 in Florida. The research revealed a positive impact for the mathematics program in terms of similarity between students’ perceptions of their actual and preferred classroom environment.

The validity of the MCI, and findings of a more positive learning environment among students using science kits in terms of higher student satisfaction and cohesiveness, was reported by Scott Houston, Fraser and Ledbetter (2008) for 588 grade 3–5 students in Texas.

For a large sample of 2835 grade 4–6 students in the urban school district of Washington State, Sink and Spencer (2005) found that the scales of Cohesiveness, Competitiveness, Friction and Satisfaction in the MCI were psychometrically sound.

2.2.2.6 Questionnaire on Teacher Interaction (QTI)

The work of Theo Wubbels in identifying the importance of the student and teacher interactions led to the development of the Questionnaire on Teacher Interaction (QTI) (Creton, Hermans, & Wubbels, 1990; Wubbels & Brekelmans, 2005, 2012; Wubbels & Levy, 1993). The QTI is focussed on the significance and depth of quality of interpersonal relationships between teachers and students, as well as “drawing a theoretical model of proximity (cooperation–opposition) and influence (dominance–submission)” (Fraser, 2012, p. 1200) which acknowledges that student behaviour could affect teacher–student interaction and that a teacher’s behaviour could also affect students’ interactions in the classroom. The QTI was developed to assess student perceptions on eight teacher behavioural aspects represented by eight dimensions involving Leadership, Helpful/Friendly, Understanding, Student Responsibility/Freedom, Uncertain, Dissatisfied, Admonishing and Strict. Each item is scored on a five-point frequency scale ranging from Never (0) to Always (4). The

original Dutch version of the QTI consisted of eight scales and 77 items; however, a shorter version was developed with eight scales and a total of 48 items and the convenience of hand scoring (Wubbels & Brekelmans, 2005).

Considering the relationship between the teacher and the students as a whole class, compared to the teacher relationship with each individual student, Den Brok, Brekelmans and Wubbels (2006) investigated student perceptions using a multilevel design to compare the structure of the traditional QTI and a form developed specifically to measure teachers' relations with individual students. They concluded that, in general, the relationship of the teacher with individual students in terms of the perceptions of influence and proximity is stronger than the teachers' relationship with the class as a whole.

The development of the QTI began at the senior high-school level in the Netherlands, with further development involving cross-validation and comparative work conducted at various grade levels in the USA (Wubbels & Levy, 1993), Australia (Fisher, Henderson & Fraser, 1995) and Singapore (Goh & Fraser, 1996). Further developments led to a modified and simpler 48-item version developed and validated by Goh and Fraser (1996) in Singapore. Validating the QTI in different countries and different languages led to Scott and Fisher (2004) validating a version of the QTI in Brunei Darussalam in standard Malay with 3104 students in 136 elementary-school classrooms. The study revealed that achievement was positively related to 'cooperative behaviours' and negatively related to 'submissive behaviours'. Quek, Wong and Fraser (2005) validated an English version of the QTI with 497 gifted and non-gifted secondary chemistry students in Singapore. They reported some differences between gifted and non-gifted students as well as sex-related differences in QTI scores.

The use of the QTI was further strengthened in Korea by the work of Lee, Fraser and Fisher (2003), who translated and validated the QTI with 439 science students and by Kim, Fisher and Fraser (2000) with 543 students. Fraser, Aldridge and Soerjaningsih (2010) translated and validated the QTI in Indonesia with a sample of 422 university students.

2.2.2.7 Science Laboratory Environment Inventory (SLEI)

The science laboratory classroom environment is unique compared with a traditional classroom. Therefore, an instrument which is specifically designed to assess the science laboratory environment was developed for senior high-school and higher-education students (Fraser, Giddings & McRobbie, 1995; Fraser & McRobbie, 1995). The Science Laboratory Environment Inventory (SLEI) has five scales, Student Cohesiveness, Open-endedness, Integration, Rule Clarity and Material Environment, with 7 items each. The 5-point frequency response scale includes Almost Never, Seldom, Sometimes, and Often to Very Often. As science laboratory activities often are open-ended, an Open-endedness scale was included.

The SLEI was validated with a sample of over 5447 students in 269 classes in six different countries (USA, Canada, England, Israel, Australia and Nigeria). In Australia, Fraser and McRobbie (1995) cross validated the SLEI with 1594 students in 92 classes, whilst Fisher, Henderson and Fraser (1997) cross-validated the SLEI with 489 senior high-school biology students.

The SLEI was used by Lightburn and Fraser (2007) in a US study involving a sample of 761 high-school biology students in 25 classes in investigating the pedagogical effectiveness of using anthropometric activities as part of the biology curriculum. They reported the SLEI's validity (factor structure, internal consistency reliability and ability to differentiate between classrooms) and a positive effect for using anthropometric activities in terms of student outcomes and classroom environment.

In Korea, the SLEI was translated into the Korean language by Fraser and Lee (2009) in a study of differences in student perceptions between classroom environments in science and humanities involving a sample of 439 high-school students. The researchers reported sound factorial validity and internal consistency reliability for the SLEI and that it could differentiate between the perceptions of students in different classes. In this study, Fraser and Lee (2009) examined differences in student perceptions of their learning environment in three different streams, namely, science-independent, science-oriented and humanities streams with each involving different curricula and different exposure to science laboratory activities. The study revealed

that students in the science-independent stream generally perceived their classroom learning environments more favourably than did students in the other streams. In addition, associations were found between various measures of students' attitudes and their perceptions on the SLEI scales.

2.2.2.8 Constructivist Learning Environment Survey (CLES)

In the early 90s, a focus on constructivist learning theory (which espouses a belief that learners are actively involved in a process of developing meaning and constructing knowledge as opposed to learners being passive recipients of information) led to the development of the Constructivist Learning Environment Survey (CLES). Taylor, Fraser and Fisher (1997) developed the CLES to enable teachers to reflect on their teaching and utilise action research to make improvements to their learning environment.

The CLES comprises five scales, Personal Relevance, Uncertainty, Critical Voice, Shared Control, and Student Negotiation, with a total of 36 items. A five-point frequency scale ranges from Almost Never to Almost Always. The CLES is best used with secondary students. Taylor, Fraser and Fisher (1997), in a study involving a sample of 494 Australian secondary students in 41 grade 8 and 9 classes in 13 schools and 1600 grade 9–12 science students in Texas, reported that the CLES revealed sound factorial validity and internal consistency reliability.

In North Texas, an innovative science teacher professional development programme was evaluated with 1079 students in 59 classes by Nix, Fraser and Ledbetter (2005). The study revealed strong support for the validity of the CLES and students of these teachers perceived their classrooms more favourably than students not involved in the professional development.

In a cross-national study, Aldridge, Fraser, Taylor and Chen (2000) administered the CLES to 1081 students in 50 classes in Australia and a Mandarin version of the CLES to 1879 students in 50 classes in Taiwan. The researchers reported sound factor structure and internal consistency reliability for all scales and that the CLES could differentiate significantly between students in different classes. In terms of

constructivism, the study revealed that Australian classes were perceived to be more constructivist than classes in Taiwan.

The CLES was modified and translated into Spanish by Piero and Fraser (2009) and administered in English and Spanish to 739 Grade K–3 science students in Miami, USA. The study revealed that the modified English and Spanish versions were valid and reliable when used with very young children. The CLES was also translated into Korean (Kim, Fisher & Fraser, 1999) and administered to 1083 students in 24 grade 10 science students. This study supported a strong factor structure and reliability of the Korean version of the CLES. Both of these studies reported positive associations between students' attitudes and classroom learning environment.

Aldridge, Fraser and Sebela (2004), in their study on the promotion of reflective practice of teaching in mathematics, administered an English version of the CLES to 1864 grade 4–6 mathematics students in 43 classes in South Africa. The researchers cross-validated the CLES in terms of factorial validity, internal consistency reliability and ability to differentiate between classrooms. At both the individual and class mean levels of analysis and for a preferred and an actual form, the internal consistency reliability was found to be satisfactory. The findings suggested that the CLES was valid and reliable when modified for use in South Africa.

Koh and Fraser (2014) reported on a study which involved pre-service teachers using a pedagogical model which focusses on strategies for student engagement. Using an experimental group of 2216 secondary school students and a control group of 991 students in Singapore, the effectiveness of the model was evaluated using a modified version of actual and preferred forms of the CLES. The findings supported that a modified CLES was valid and reliable for the assessment of students' perceptions of their learning environment in business studies. Koh and Fraser recommended that future evaluations focus on the efficacy of reducing the gap between actual and preferred perceptions of the learning environment.

2.2.2.9 What Is Happening In this Class? (WIHIC) Questionnaire

The What Is Happening In This Class? (WIHIC) questionnaire has drawn on the best of a large number of previous learning environment questionnaires and is the most commonly used questionnaire in this field (Fraser, Fisher & McRobbie, 1996). The WIHIC has a separate Class form which assesses students' perceptions of the class as a whole and a Personal form which assesses students' personal perceptions of their role in the classroom. Because the WIHIC was the main instrument used in my study, it is discussed in further detail in Section 2.2.3.

2.2.2.10 Technology-Rich Outcomes-Focussed Learning Environment Inventory (TROFLEI)

The Technology-Rich Outcomes-Focussed Learning Environment Inventory (TROFLEI) incorporates all of the WIHIC's seven scales, namely, Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Investigation, Cooperation and Equity (see Section 2.2.3 for further information) and three additional scales which assess the extent to which teachers cater for student individual learning needs (Differentiation from the ICEQ), the extent to which technology is used in the process of learning (Computer Usage) and the extent to which teachers treat students as young adults and encourage responsibility (Young Adult Ethos). The TROFLEI has 10 scales with eight items in each scale for a total of 80 items and is responded to using a five-point frequency scale of Almost Never, Seldom, Sometimes, Often and Almost Always. The TROFLEI has actual and preferred forms (Aldridge & Fraser, 2008).

Extensive research was conducted involving the validation and application of the TROFLEI using a sample of 2317 grade 11 and 12 students from Western Australia and Tasmania. The TROFLEI's strong factorial validity and internal consistency reliability were supported for both the actual and preferred forms. In addition, the actual form showed a capacity to differentiate between perceptions of students in different classes (Aldridge & Fraser, 2008).

Aldridge, Dorman and Fraser (2004) conducted research using multi-trait-multi-method modelling with a sample of 772 students in Western Australia and 477 students in Tasmania, with results showing the TROFLEI's strong construct validity and

psychometric properties. Other uses of the TROFLEI include Aldridge and Fraser's (2008) study into the success of an innovative new school in promoting an outcomes-focussed curriculum over a four-year period; the efficacy of the school's educational programme was supported. Dorman and Fraser (2009) established associations between affective outcomes and classroom environment perceptions based on the TROFLEI.

Koul, Fisher and Shaw (2011) reported the application of the TROFLEI in secondary school science classes in New Zealand involving a sample of 1027 high-school students from 30 classes. Their study supported the validity of the instrument and associations between the scales of the TROFLEI and actual and preferred learning environment, year levels and gender. Welch, Cakir, Peterson and Ray (2014) established the cross-cultural reliability and validity of the TROFLEI using a sample of 1110 students in both Turkey (980) and the USA (130).

Earle and Fraser (2016) evaluated the effectiveness of an online mathematics software program in terms of students' perceptions of their learning environment and attitudes towards mathematics involving a sample of 949 students in 49 classrooms in Florida. Using the TROFLEI and scales selected from the Test of Mathematics-Related Attitudes (TOMRA), data analyses supported the factorial validity, internal consistency reliability and discriminant validity of the TROFLEI and TOMRA. The study revealed associations between students' perceptions of their classroom environment and their attitudes to mathematics, with student attitudes being more positive in classrooms with more Teacher Support, Involvement, Investigation and Cooperation.

McDaniel and Fraser (2016) investigated the no significant difference phenomenon for technology-based learning environments with a sample of 605 grade 6-8 students in Texas. The TROFLEI was used in a pretest-posttest design over an eight-month period to evaluate effectiveness. The findings strongly supported the factorial validity and internal consistency reliability of the scales of the TROFLEI. Small differences between pretest and posttest scores for the TROFLEI scales were reported, which demonstrate that technological integration into core curriculum might neither result in

any educational advantages nor produce any disadvantages to learning.

2.2.2.11 Constructivist-Oriented Learning Environment Survey (COLES)

In the context of teacher action research and teachers' reflection on their work, the Constructivist-Oriented Learning Environment Survey (COLES) was developed to provide feedback to teachers. The COLES utilises a number of scales from the WIHIC, namely, Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Cooperation and Equity, two scales from the TROFLEI, namely, Differentiation and Young Adult Ethos, and one scale from the CLES, Personal Relevance. Two new COLES scales developed to encompass assessment are Formative Assessment and Assessment Criteria. The Formative Assessment scale measures the extent to which students perceive that formative assessment tasks are positive to their learning experience, whilst the Assessment Criteria scale measures the extent to which task criteria are explicit, clear and transparent (Aldridge, Fraser, Bell & Dorman, 2012).

With a sample of 2043 grade 11 and 12 students in 147 classes in nine schools in Western Australia, strong factorial validity and internal consistency reliability for both the actual and preferred forms and a capability of differentiating between the perceptions of students in different classes were reported by Aldridge, Fraser, Bell and Dorman (2012). Bell and Aldridge (2014) reported a study entitled Student Voice, Teacher Action Research and Classroom Improvement over a period of three years using a sample of 10345 students in 684 classes in 29 regional and metropolitan co-educational high schools in Western Australia. Using a framework for construct validity developed by Trochim and Donnelly (2008), the COLES was found to be valid and reliable for assessing students' perceptions of their classroom learning environment, their attitudes and academic self-efficacy beliefs.

2.2.3 What Is Happening In this Class? (WIHIC)

This section describes in greater detail the What Is Happening In this Class? (WIHIC), which is the learning environment instrument that was chosen for my study. The background and development of the WIHIC is discussed in Section 2.2.3.1. The validity and application of the WIHIC in past studies is discussed in Section 2.2.3.2.

2.2.3.1 Background to the WIHIC

The What Is Happening In this Class? (WIHIC) was developed by Fraser, Fisher and McRobbie (1996) and is the most frequently-used learning environment instrument in classroom research for the last 20 years (Fraser, 2014). The WIHIC incorporates scales from previous studies found to be significant predictors of outcomes (Fraser, Fisher & McRobbie, 1996) and additional scales which assess the concerns in classrooms such as constructivism and equity. The WIHIC also addressed the concern that previous learning environment instruments did not distinguish between the student's perceptions of the class as a whole (Class Form) in contrast to the student's personal perceptions of the student's role (Personal Form, Fraser et al., 1996)

The first version of the WIHIC contained 9 scales with 10 items per scale for a total of 90 items with Student Cohesiveness, Teacher Support, Involvement, Autonomy/Independence, Investigation, Task orientation, Cooperation, Equity and Understanding. The WIHIC uses the same frequency response format as previous instruments, namely, Almost Never, Seldom, Sometimes, Often and Almost Always. During its development, actual versions of the class and personal forms were administered to a sample of 355 students in 17 grade 9/10 mathematics and science classes in five Australian schools. Following detailed factor analysis, the WIHIC was refined to a 54-item seven-scale questionnaire, with the Autonomy/Independence and Understanding scales not able to provide satisfactory statistical measures. Further testing resulted and a second version with Autonomy/Independence reinstated and with 8 scales with 10 items in each for a total of 80 items. Extensive testing followed in Australia (1081 students in 50 classes) and Taiwan (1879 students in 50 classes) after the WIHIC was translated into Chinese for the Taiwan study (Aldridge, Fraser &

Huang, 1999). This led to the final version of the WIHIC with seven scales and 8 items per scale for a total of 56 items. Aldridge and Fraser (2000) reported strong factorial validity and internal consistency reliability and that each scale is able to differentiate between the perceptions of students in different classrooms.

2.2.3.2 Validity and Application of the WIHIC in Past Studies

Over the last 20 years, the WIHIC has been shown to be valid and reliable in many studies across many countries and by different researchers. It has become the most-frequently used classroom instrument in the world today (Fraser, 2014). Dorman (2003) reported a very comprehensive validation of the WIHIC in a cross-national study with a sample of 3980 high-school students from Australia, UK and Canada. He used confirmatory factor analysis (CFA) which supported the seven-scale a priori structure and used multi-sample analyses within structural equation modelling to substantiate the invariant factor structures for the three grouping variables of country, grade level and student sex. When he conducted a second study in which he used both the actual and preferred forms of the WIHIC with a sample of 978 secondary-school students from Australia, the research provided “strong evidence of the sound psychometric properties of the WIHIC” (Dorman, 2003, p. 179).

As discussed above, the WIHIC has been used in a cross-national study in Taiwan and Australia by Aldridge, Fraser and Huang (1999) and Aldridge and Fraser (2000). Fraser, Aldridge and Adolphe (2010) conducted cross-national research in Australia (567 students) and Indonesia (594 students) in 18 secondary science classes. A modified version of the WIHIC was translated from English into Bahasa Indonesia and administered simultaneously in both countries. Principal components factor analysis with varimax rotation supported the validity of the revised structure of the WIHIC. In addition, the study revealed some differences in students’ perceptions of their learning environment between countries and between sexes, and positive associations between classroom learning environment and student attitudes to science.

Zandvliet and Fraser (2004, 2005), in their study involving a sample of 1404 students in 81 classes in Australia and Canada, reported good factorial validity and internal consistency reliability for 5 scales of the WIHIC, namely, Student Cohesiveness,

Involvement, Autonomy/Independence, Task Orientation and Cooperation. Using satisfaction as a dependent variable, Zandvliet and Fraser (2005) reported that the classroom psychosocial environment was significantly associated with students' satisfaction. In another Canadian study involving 1173 mathematics and science secondary students using laptop computers in their classrooms, Fraser and Raaflaub (2013) found that males and females perceived their actual learning environment much the same, but that females preferred to use laptop computers less.

The factorial validity and the reliability of the WIHIC have been supported in many more studies across the world and it has been successfully translated into many languages. In a study (in English) involving 2310 geography and mathematics students in Singapore, Chionh and Fraser (2009) demonstrated that the actual and preferred forms had strong factorial validity and reported associations with learning environment and attitudes, self-esteem and achievement. Khoo and Fraser's (2008) study in Singapore involving a sample of 250 adults attending computer courses showed that males perceived more trainer support and involvement but less equity. Koul and Fisher (2005), in a study involving 1021 science students in 31 classes in India, showed differences in classroom environment depending on cultural background

In a study in Indonesia, a sample of 2498 university computing students in 50 computing classes used the Bahasa Indonesia version of the WIHIC (Margianti, Fraser & Aldridge, 2001). Also in Indonesia, Wahyudi and Treagust (2004) validated the WIHIC after translating it into Bahasa with 1400 lower-secondary science students in 16 schools. MacLeod and Fraser (2010) administered an Arabic version of the WIHIC in the United Arab Emirates to 763 college students in 82 classes. Afari, Aldridge, Fraser and Khine (2013) also verified the validity of a modified WIHIC in the United Arab Emirates with a sample of 352 mathematics students attending three higher-education institutions, as well as reporting that the two scales of Teacher Support and Personal Relevance were important predictors of enjoyment of mathematics lessons and self-efficacy. The WIHIC was translated into Korean in a study by Kim, Fisher and Fraser (2000) involving 543 grade 8 science students in 12 schools. The study confirmed the validity of the WIHIC and revealed sex-related differences in students'

perceptions.

The WIHIC has been extensively used in studies in the USA. A study in California involved using the WIHIC with 665 middle-school science students in 11 schools in investigating the influence of gender, socioeconomic status, ethnicity and class size on the perceptions of learning environment (den Brok, Fisher, Rickards, & Bull, 2006). Ogbuehi and Fraser (2007) used scales from three instruments (WIHIC, CLES and TOSRA) to evaluate an innovative teaching strategy for enhancing classroom environment, students' attitude and conceptual development with 661 middle-school mathematics students. They reported that innovative teaching strategies promoted task orientation.

Wolf and Fraser (2008) conducted a study of inquiry-based laboratory activities involving 1434 middle-school science students in 71 classes in New York. They reported that inquiry was differentially effective for males and females and also promoted cohesiveness in the classroom. Pickett and Fraser (2009), in a study of 573 primary-school students, evaluated a mentoring program for beginning teachers. The WIHIC demonstrated strong factorial validity and was used to gather feedback about classroom learning environment before and after intervention strategies.

In South Africa, Aldridge, Fraser and Ntuli (2009) utilised learning environment assessments to improve teaching practices among in-service teachers undertaking a distance-education programme. The study involved 31 teachers who administered a primary-school version of the WIHIC questionnaire to 1077 students in order to determine preferred and actual learning environments. This research was unique in that it provided the first learning environment survey at the primary-school level in South Africa and cross-validated an IsiZulu version of the WIHIC. The study supported the success of the use of the learning environment questionnaire as a tool for teachers for guiding improvements to the classroom learning environment.

Investigating sex, grade-level and stream differences in learning environment and attitudes to science in Singapore primary schools, Peer and Fraser (2015) used six scales of the WIHIC, together with scales from the CLES and TOSRA, with a sample of 1081 students in 55 classes. Overall the study reported strong factorial validity and

internal consistency reliability for the WIHIC, CLES and TOSRA. The study was significant as the first research in primary science classes in Singapore using learning environment instruments such as the WIHIC and CLES.

Cohn and Fraser (2016) reported a study conducted in New York involving 1097 grades 7–8 students in investigating the effectiveness of student response systems in terms of learning environment, attitudes and achievement. A new questionnaire (How Do You Feel About This Class? – HDYFATC) was based on numerous scales of the WIHIC and one scale from the TOSRA. The findings showed the versatility of the WIHIC because the HDYFATC displayed sound factorial validity and internal consistency reliability, as well as being able to differentiate between perceptions of students in different classrooms. In addition, the study suggested that the use of a student response system in science classrooms can help to improve students' perceptions of their learning environment, attitudes to science and achievement.

Long and Fraser (2015) evaluated the effectiveness of two alternative middle-school science curricula (a general science and topic-specific science model) with 367 grade 8 science students in Texas. Using scales of the WIHIC and one scale from the TOSRA, the study demonstrated the validity and reliability of the survey instruments, as well as showing that science was enjoyed more by students following a topic-specific sequence. Whereas the general science model was more effective than the topic-specific model for Hispanic students in terms of Task Orientation, but both models were equally effective for Caucasian students.

The effectiveness of virtual laboratories in terms of learning environment, attitude and achievement was investigated by Oser and Fraser (2015) for a sample of 322 grades 8–10 students in 12 classes in the USA. No significant differences emerged between groups using this technology, suggesting that virtual laboratories could be used as a supplementary method without negatively affecting students. This study's findings regarding technology use were similar to McDaniel and Fraser (2016), although different learning environment tools were used.

The WIHIC was successfully validated in studies involving young students and their

parents by Allen and Fraser (2007) and Robinson and Fraser (2013). To understand the dynamics of the classroom environment, the WIHIC has been found to be valid and useful in studies at various grade levels, in various languages and in many countries across the world. Each study cited strong factorial validity and internal consistency reliability based on large samples. This attests to the usefulness and versatility of the WIHIC in learning environments research. Section 3.5.1 provides further details of the development of the WIHIC as the learning environment instrument that was used in my study.

2.2.4 Past Research Involving Learning Environment

Past research involving the use of learning environment instruments provides a diverse range of applications in terms of research traditions, research methods and models which are applicable to my study (Fraser, 1998b, 2012; Fisher & Khine, 2006).

Three types of past research of relevance to my study are summarised in this section:

- Associations between Student Outcomes and Classroom Learning Environment (Section 2.2.4.1)
- Evaluation of Educational Innovations (Section 2.2.4.2)
- Use of Qualitative Methods (Section 2.2.4.3).

2.2.4.1 Associations between Student Outcomes and Classroom Learning Environment

Studies of associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classroom learning environment (Fraser & Fisher, 1982; Haertel, Walberg & Haertel, 1981; McRobbie & Fraser, 1993; Fraser, 2007, 2012) is one of the strongest traditions in learning environment research. Fraser (1998a) reported numerous studies in science education which consistently replicated associations between classroom perceptions and student outcome measures for a variety of learning environment instruments and various samples (Fisher, Henderson & Fraser, 1997; McRobbie & Fraser, 1993; Teh & Fraser, 1994; Wong & Fraser, 1996; Young & Fraser, 1993). In a meta-analysis involving 734

correlations from 12 studies involving 823 classes, eight subject areas, 17,805 students, learning posttest scores and regression adjusted gains were consistently and strongly associated with cognitive and affective learning outcomes (Haertel et. al., 1981). Across many countries, such as the United States, Australia, Canada and Asia, numerous past studies have substantiated that students perceptions of their learning environment are strong predictors of student outcomes (Byrne, Fraser & Hattie, 1986; Chionh & Fraser, 2009; Den Brok, Fisher, Rickards & Bull, 2006; Dorman, 2001; Fraser & Fisher, 1982; McRobbie & Fraser, 1993; Zandvliet & Fraser, 2005).

More recent studies relevant to my study involving associations between the learning environment and students' cognitive and affective learning outcomes include Afari, Aldridge, Fraser and Khine (2013). This study with 352 students in 33 classes in the UAE showed a statistically significant simple correlation between attitude scales and WIHIC scales with the individual as the unit of analysis, but not with the class mean as the unit of analysis. Multiple regression analysis revealed that enjoyment of lessons was greater in classrooms with more Teacher Support, Cooperation and Personal Relevance and that Academic Efficacy was higher in classes with more Personal Relevance.

In Maryland, Martin-Dunlop (2016) assessed 355 students' perceptions of their undergraduate biology learning environment at a historically African-American institution. Using learning environment scales from the WIHIC and other previously-validated surveys as well as two attitude scales, it was found that overall learning environment was strongly correlated with enjoyment of lessons ($R=0.54$; $p<0.01$). In particular, Involvement was an independent predictor of students' Academic Self-Efficacy. In another study in California, Rita and Martin-Dunlop (2011) assessed the perceptions of 146 gifted and 115 non-gifted high-school biology students using the WIHIC. Data analyses revealed statistically significant associations between actual learning environment and achievement. Furthermore, Teacher Support, Investigation and Equity were statistically significant independent predictors of student achievement.

Ogbuehi and Fraser (2007) reported associations between classroom environment and

students' attitudes to mathematics using a modified questionnaire with scales from the WIHIC, CLES and TOMRA with 661 middle-school students in 22 classes in California, USA.

In Uganda, Opolot-Okurut (2010) reported a study involving secondary students' perceptions of their mathematics classroom learning environment and their association with motivation towards mathematics. Using a sample of 81 students and the WIHIC, associations between learning environment and motivation were examined. Considering the difference between low-performing (LP) and high-performing (HP) schools, Opolot-Okurut found that, in high-performing schools, students perceived their classroom environment more favourably on the Cooperation scale and that, in low-performing schools, students perceived the classroom environment more favourably for the Teacher Support and Involvement scales. In addition, students' motivation was reported as positively and significantly associated with all WIHIC scales except for Cooperation in the low-performing school. Multiple regression analysis showed that Task Orientation was a significant independent predictor of student motivation in a low-performing school.

Other significant and important past studies which used the WIHIC in investigating associations between classroom learning environment and student outcomes include Aldridge and Fraser (2000) who investigated associations between learning environment and Enjoyment of Subject in Taiwan and Australia, Fraser, Aldridge and Adolphe (2010) who investigated associations between learning environment and attitudes in Indonesia and Australia, and Chionh and Fraser (2009) who investigated associations between learning environment and attitudes, achievement and self-esteem in Singapore.

Other learning environment instruments have been used in past studies to investigate associations with student outcomes. The Technology-Rich Outcomes-Focussed Learning Environment Inventory (TROFLEI) was used in New Zealand by Koul, Fisher and Shaw (2011) with 1027 students in 30 classes to investigate the perceptions of students of their secondary-school science classes. Statistically significant associations were found between the TROFLEI scales and Attitude to Subject, Attitude

to Technology and Academic Efficacy. Another study using the TROFLEI was conducted in India with 705 students from 15 classes to investigate the impact of technology-supported classroom learning environments involving modern information and communication technologies. Gupta and Fisher (2012) reported associations between TROFLEI scales and three learner outcomes, namely, Attitudes, Academic Efficacy and Achievement.

Fraser and Lee (2009) conducted a study involving 439 students in Korea with the Science Laboratory Environment Inventory (SLEI) in order to investigate the learning environment of senior high-school science laboratory classrooms. Significant simple correlations were found between learning environment and attitude scales. In particular, statistically-significant independent associations were found between a number of SLEI scales and attitude scales and, more importantly, Integration was a statistically-significant independent predictor of the attitude scales when the other SLEI scales were mutually controlled.

Sivan and Chan (2013) conducted a study into teacher interpersonal behaviour and secondary students' cognitive, affective and moral outcomes in Hong Kong. With a sample 612 grade 9 students from 16 Mathematics, Chinese and English classes across six schools, the Questionnaire on Teacher Interaction (QTI) was used to investigate the effect of teacher interpersonal behaviour on students' outcomes. Stronger associations between student outcomes and those QTI scales with positive qualities in Leadership, Helpful/Friendly, Understanding, Student Responsibility and Freedom were found compared with QTI scales displaying negative qualities of Uncertain, Admonishing and Strict.

Table 2.2 provides a summary of 17 studies involving the WIHIC or scales from the WIHIC in investigating associations between classroom learning environment and student outcomes. The table includes the author(s) of the study, the country, language, sample size and outcome variable(s).

Table 2.2: Studies Involving the WIHIC in Investigating Associations between Classroom Learning Environment and Student Outcomes

References	Country(ies)	Language(s)	Sample(s)	Outcome Variable
Aldridge & Fraser (2000)	Australia Taiwan	English Mandarin	1081 (Australia) and 1879 (Taiwan) junior high school science students	Enjoyment
Fraser, Aldridge & Adolphe (2010)	Australia Indonesia	English Indonesian	1161 students (594 Indonesian students and 567 Australian students)	Attitudes
Chionh & Fraser (2009)	Singapore	English	2310 grade 10 geography and mathematics students	Attitudes Achievement Self-esteem
MacLeod & Fraser (2010)	UAE	Arabic	763 college students in 82 classes	Attitude
Ogbuehi & Fraser (2007)	California, USA	English	661 middle-school mathematics students	Attitudes
Wolf & Fraser (2008)	New York, USA	English	1434 middle-school physical science students in 71 classes	Attitudes Achievement
Zandvliet & Fraser (2004, 2005)	Australia Canada	English	1404 students in 81 networked classes	Attitudes
Afari, Aldridge, Fraser & Khine (2013)	UAE	Arabic	352 college students in 33 classes	Enjoyment Academic efficacy
Velayutham, Aldridge & Fraser (2012)	Australia	English	1360 grade 8,9 & 10 science students	Motivation Self-regulation
Martin-Dunlop & Fraser (2008)	California, USA	English	525 female university science students in 27 classes	Attitude
Martin-Dunlop (2016)	Maryland, USA	English	355 undergraduate biology students in 19 classes	Attitude Self-efficacy
Rita & Martin-Dunlop (2011)	USA	English	146 Grade 10 gifted Biology students and 115 non-gifted students	Achievement
Adamski, Fraser & Peiro (2013)	Florida, USA	Spanish English	223 Grade 4-6 students in 9 Spanish speaking classrooms	Attitudes Achievement
Peer & Fraser (2013)	Singapore	English	1081 students in 55 classes	Attitudes
Fraser & Raaflaub (2013)	Ontario, Canada	English	1173 Grade 7-12 in 73 mathematics and science classes	Attitudes
Robinson & Fraser (2013)	Florida, USA	English	172 Kindergarten students in 6 classes	Achievement Attitudes
Helding & Fraser (2012)	Florida, USA	English	924 students in 38 grade 8 and 10 science classes	Attitudes Achievement

Adapted from Fraser (2012) with permission

2.2.4.2 *Evaluation of Educational Innovations*

Evaluation of educational innovations have involved the impact of innovative new learning strategies in terms of student perceptions of their classroom learning environment and often student outcomes too. Learning environment instruments can provide a valuable source of process criteria in the evaluation of educational innovations (Fraser, 2012). A growing number of studies over the last 20 years have involved these evaluations (Aldridge & Fraser, 2008; Fraser, 1979; Khoo & Fraser, 2008; Lightburn & Fraser, 2007; Maor & Fraser, 1996; Nix, Fraser and Ledbetter, 2005; Teh & Fraser, 1994). Other recent studies that have contributed to this body of research are described below.

Martin-Dunlop and Fraser (2008) evaluated the impact of an innovative science course for prospective elementary teachers at a large urban university in Southern California with a sample of 525 female students enrolled in 27 classes. Perceptions of the learning environment were measured using scales from the WIHIC and SLEI. Attitudes were also measured using scales from the TOSRA. This study replicated past research with significant improvements in learning environment and attitudes with the largest gains observed in Open-Endedness and Material Environment (effect sizes over 1.5 standard deviations).

A study of middle-school students in California with a sample of 661 students from 22 classrooms in four inner city schools involved the effectiveness of using innovative teaching strategies for enhancing the classroom environment, students' attitudes and conceptual development. Ogbuehi and Fraser (2007), using scales from the CLES, WIHIC and TOMRA, found that, relative to a control group, the experimental group which experienced the innovative teaching strategy had higher learning environment, attitude and mathematical understanding scores.

Wolf and Fraser (2008) compared inquiry and non-inquiry laboratory teaching in terms of 1,434 middle-school physical science students' perceptions of their classroom learning environment, attitudes towards science and achievement. For a subsample of 165 students in 8 classes, inquiry instruction promoted more Student Cohesiveness

than non-inquiry instruction and inquiry-based laboratory activities were found to be differentially effective for male and female students. The innovative strategy appears to have benefited students in terms of developing stronger support systems, working more collaboratively, independently and exploring the topics in greater detail.

The effectiveness of using an innovative Student Response System (SRS) was the subject of a study by Cohn and Fraser (2016). For a sample of 1097 grade 8 and 9 students with 532 students using the SRS and 562 students as a control group in New York, Cohn and Fraser administered scales from the WIHIC and one scale from the TOSRA. Students who used the innovative SRS system had statistically significantly higher scores for all learning environment scales compared with the control group, with effect sizes ranging from 1.96 to 2.46 standard deviations. In addition, SRS students enjoyed their science classes more than the control group, with an effect size of 2.19 standard deviations, and also demonstrated higher academic achievement with an effect size of 1.17 standard deviations.

Afari et al. (2013) involved 352 students in 33 classes in the United Arab Emirates in examining the effectiveness of introducing games into college-level mathematics classes in terms of improving students' perceptions of their learning environment and their attitudes towards mathematics. Using a modified WIHIC and Enjoyment of Mathematics and Self-Efficacy scales translated into Arabic, they found that students involved in these activities perceived statistically significantly higher posttest levels of Teacher Support, Involvement and Personal Relevance, Enjoyment and Academic Efficacy. However, the effect sizes for the five scales were small, suggesting that any changes were small in magnitude.

McDaniel and Fraser (2016) evaluated the effectiveness of integrating technology across the curriculum in terms of students' perceptions of their learning environments. The TROFLEI was administered to 605 grades 6–8 students in Texas for core curriculum subjects. Using a pretest and posttest across an eight-month period while students experienced this innovative strategy, findings suggested that integrating instructional technology across core curriculum areas was neither advantageous nor disadvantageous in terms of classroom learning environment. This study contributes

to the growing use of learning environment assessments as a source of process criteria of effectiveness in evaluating educational innovations (Fraser, 2012).

2.2.4.3 Use of Qualitative Methods in Learning Environment Research

My study utilised a mixed-methods approach which combined quantitative data from learning environment, attitude and achievement scales with classroom observations and staff and student interviews. Creswell (2008) refers to the benefit of both quantitative and qualitative data working together to provide a better understanding of the research problem. According to Tobin and Fraser (1998, p. 639), “we cannot envision why learning environment researchers would opt for either qualitative or quantitative data, and advocate the use of both in an effort to obtain credible and authentic outcomes”. Significant progress has been made in learning environment research in drawing together the strengths of both quantitative and qualitative methods.

Classroom environments were investigated in Taiwan and Australia using multiple research methods in cross-national studies (Aldridge & Fraser, 2000; Aldridge, Fraser & Huang, 1999; Aldridge, Fraser, Taylor & Chen, 2000). Using scales from the WIHIC/CLES and scales from the TOSRA, the researchers developed a Mandarin version for use in Taiwan. The sample for the quantitative methods included 1081 grades 8–9 science students from 50 classes in Australia and 1879 grades 7–9 science students in Taiwan. The quantitative data provided a starting point from which qualitative data were collected using classroom observations, interviews with teachers and students, and narrative stories written by the researchers. Analysis of the initial interviews raised deeper questions about the learning environment and cultural aspects. Observations of classes led to a source for student interview questions and further questions about students’ perceptions of their learning environment. In terms of teacher interviews, this led to deeper questions about teacher actions and whether socio-cultural factors influence classroom environments. As an interpretive study, the research focussed on examining socio-cultural factors which could influence learning environments in different countries.

Fraser and Tobin (1991) and Tobin and Fraser (1998) reported studies about exemplary teaching practice which utilised an interpretative research methodology (Erickson,

1986) in which data collected was primarily qualitative and based on direct observations of classroom learning environments, interviews with teachers and students, and examination of a range of resources such as student work and curriculum materials. Regular observations and field notes were considered and discussed by the researchers involved. In addition, student perceptions of their psychosocial learning environment were measured using a range of learning environment instruments. This methodology was resource intensive in terms of time and people, encompassing 22 teachers with a minimum of 8 classroom observations each. The data collected provided insight into the teaching methods of exemplary teachers in science and mathematics and, coupled with quantitative measures, provided more in-depth understanding. The study suggested that learning environment instruments could differentiate between exemplary teachers and non-exemplary teachers. Exemplary teachers created more favourable learning environment conditions compared to non-exemplary teachers.

Aldridge and Fraser (2008), in their study of outcomes-focussed learning environments, reported the use of feedback from the TROFLEI to improve learning environments using teacher action research. Using qualitative data to explore quantitative results provided a more holistic analysis and explanation of the differences found in the study.

Allen and Fraser (2007) investigated parents' and students' perceptions of the learning environment using a modified version of the WIHIC. Using a sample of 520 students aged 9–11 years from 22 classes in 3 schools in South Florida. 120 parents from the school, where the researcher was based, completed the questionnaire. The study also included a qualitative fine-grain component with 10 parents and their children being interviewed using various techniques including focus-group, paired (parent–child) and individual interviews. Whilst the quantitative findings indicated that students generally preferred a more favourable learning environment, the qualitative data provided greater clarity and indicated students' satisfaction with their classroom learning environments and teachers. Overall the qualitative data offered plausible explanations for the quantitative findings.

2.2.5 Summary of Review of Learning Environment Literature

Section 2.2 reviewed literature relevant to my study from the field of learning environment. It covered historical and theoretical perspectives which led to extensive research on classroom learning environments. It encompassed the development, validation and application of well-known classroom learning environment questionnaires such as the LEI, CES, ICEQ, CUCEI, MCI, QTI, SLEI, CLES, WIHIC, TROFLEI and COLES. Because I chose to use the What Is Happening In this Class? (WIHIC) for my study, a more detailed review for the WIHIC was provided in Section 2.2.3. In Section 2.2.4, I reviewed past learning environment research in three areas relevant to my study, namely, associations between student outcomes and classroom learning environment, evaluation of educational innovations and use of qualitative methods in learning environment research.

2.3 Student Attitudes

Research into students' attitudes to studying science and mathematics has received much attention by the research community in the past 40 years (Khine, 2015; Kind & Barmby, 2011; Kind, Jones & Barmby, 2007; Osborne, Simon & Collins, 2003; Reid, 2006; Tytler & Osborne, 2012). Interest in understanding the relationship between students' perceptions of their learning environment and student outcomes has been driven by mounting evidence of a decline in the number of students choosing science and mathematics in high school (Osborne, Simon & Collins, 2003). Because attitudes were assessed in my study, the following subsections encompass defining attitudes (Section 2.3.1), the Test of Science Related Attitudes (Section 2.3.2) and academic efficacy (Section 2.3.3).

In this section on student attitudes, academic efficacy (Section 2.3.3) has been subsumed under 'attitudes' as it achieves economy and parsimony in reviewing the literature. Past studies which have similarly subsumed academic efficacy under attitudes include Aldridge and Fraser (2008), Bell and Aldridge (2014) and Martin-Dunlop (2016).

2.3.1 Defining Attitude

A particular problem has been to accurately define attitude, given that it is difficult to observe this psychological construct (Francis & Greer, 1999; Kind et al., 2007; Osborne et al., 2003). A range of concepts which relate to attitudes could be included in a definition, such as feelings, motivation, enjoyment and self-esteem. Whilst there is no unanimous agreement on a specific definition by researchers, Reid (2006, p. 4) suggests that attitude be considered under three components:

- A knowledge about the object, the beliefs, ideas component (Cognitive);
- A feeling about the object, like or dislike component (Affective); and
- A tendency-towards-action, the objective component (Behavioural).

Adediwura (2011) defined attitudes solely in terms of the affective component as positive, neutral or negative, whilst Daskalogianni and Simpson (2000) considered attitudes as bi-dimensional, comprising of two components, emotion and beliefs. Di Martino and Zan (2010) considered attitudes as the three strictly interconnected dimensions of emotional disposition, vision of mathematics and perceived competence in mathematics. Mueller (1986), on the other hand, considered attitudes as the result of consequences of events and expressed through a person's behaviour. Tapia and Marsh (2004, 2005) considered feelings and emotions in terms of value, self-confidence, enjoyment and motivation. In addition, they refer to value as a students' belief about the usefulness, worth and relevance of mathematics.

Osborne, Simon and Collins (2003) propose that attitude is more complex and includes a range of components such as perceptions of the teacher, anxiety, value, self-esteem, motivation, enjoyment, attitudes to peers and parents, achievement, nature of the classroom and fear of failure in the subject. Importantly, some researchers suggest that attitude should be considered in a narrow perspective on the basis of 'evaluative judgements' (Ajzen, 2001; Crano & Prislin, 2006). Attitude can be considered as judging on the basis of emotions to a circumstance or 'attitude object' (Crano & Prislin, 2006). This makes it clear that attitude is more than just moods or feelings.

Kind, Jones and Barmby (2007, p. 873) considered a range of views regarding the

definition of attitude proposed and that attitude should be defined as “the feelings that a person has about an object, based on their beliefs about that object”. This definition allows an attitude to subject to be measured in terms of students’ cognitive and emotional opinions about aspects of that subject, as well as to include opinions about the classroom environment, the teacher, the curriculum and the activities in the classroom (Ma & Kishor, 1997; Tapia & Marsh, 2004).

Kind, Jones and Barmby (2007) identified that measuring attitude was problematic, with long-standing issues with attitude scales including lack of clarity in descriptions and the validity and reliability of instruments. One scale from the Test of Science-Related Attitudes (TOSRA) developed by Fraser (1979, 1981a) was adapted for my study to assess Attitude to Subject. Section 3.5.3 provides more information about the development and use of the TOSRA.

2.3.2 *Validation and Use of the TOSRA*

The Test of Science Related Attitudes (TOSRA) was developed specifically to measure the progress of secondary students in their goals in science (Fraser, 1981a). Based on Klopfer’s (1971) classification of students’ attitudinal aims, the TOSRA provides seven distinct scales, namely, Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. Each scale contains 10 items, making a total of 70 items for the questionnaire. The TOSRA uses a 5-point Likert agreement response format.

The TOSRA is claimed to be useful and easy to use in terms of measuring and monitoring the development of science-related attitudes among individual students or whole classes. Significantly, it enables researchers to obtain an ‘attitude profile’ of scores for a particular group of students (Fraser, Aldridge & Adolphe, 2010). In addition, a major advantage of the TOSRA over other attitudinal instruments is that it can provide a separate score for distinct attitudinal constructs, as opposed to a single overall score.

The TOSRA has been used to evaluate educational innovations and to explore

associations between the learning environment and students' attitudes (Afari et al., 2013; Lightburn & Fraser, 2007; Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005). It has been cross-validated in several different countries. Fraser (1978) field tested the TOSRA with a sample of 1337 students in 44 classes from 11 different schools from grades 7–10 in Australia. The internal consistency reliability coefficient for each TOSRA scale was relatively high and all TOSRA scales displayed good test–retest reliability. Fraser and Butts (1982), with a sample of 712 junior high-school science students, measured student attitudes using the TOSRA's seven scales in an investigation of relationships between perceived levels of classroom individualisation and science-related attitudes. The researchers found that each TOSRA scale displayed adequate internal consistency reliability and discriminant validity.

In a more-recent study of a cross-national nature, involving 594 students in 18 classes in Indonesia and 567 students in 18 classes in Australia, Fraser, Aldridge and Adolphe (2010) investigated secondary science classrooms using the WIHIC and TOSRA. Whilst the assessment of attitudes to science was a minor part of the study, the TOSRA for both the Indonesian and Australian version exhibited sound internal consistency reliability and factorial validity.

Wong and Fraser (1996) used a modified version of the TOSRA involving a sample of 1592 final-year secondary-school chemistry students in Singapore to investigate associations between students' perceptions of their chemistry laboratory classroom environment and their attitudes towards chemistry. The researchers developed the Questionnaire of Chemistry-Related Attitudes (QOCRA) based on modified scales from TOSRA by replacing the word 'Science' with 'Chemistry'. This study was one of the first of its kind in Asia and revealed statistically significant associations between the laboratory classroom environment and students' attitudinal outcomes, as well as supporting the validity of the QOCRA.

A number of studies have used one or more scales of the TOSRA and modified these to develop the Test of Mathematics-Related Attitudes (TOMRA) by replacing the word 'Science' with 'Mathematics' and adapting it for mathematics classes (Earle & Fraser, 2016; Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005; Rosales, 2009).

Walker (2006) used the TOSRA as the basis to develop the Test of Geography-Related Attitudes (ToGRA) with a sample size of 388 Year 9 students in Texas. The 29-item ToGRA assesses Leisure Interest in Geography, Enjoyment of Geography, Career Interest in Geography.

Adamski, Fraser and Peiro (2013) used the TOSRA as the basis to develop the Test of Spanish-Related Attitudes by replacing the word 'Science' with 'Spanish'. In this study, the two scales used were Adoption of Scientific Attitudes and Enjoyment of Science Lessons, which were modified to use the word 'Spanish'.

Other studies that have successfully utilised one or more of the scales of the TOSRA in investigating associations between attitudes and learning environment include Holding and Fraser (2013), who used the one scale of, Enjoyment of Science, and Robinson and Fraser (2013), who used three scales, namely, Attitude to Science Inquiry, Adoption of Scientific Attitudes and Enjoyment of Science Lessons. Enjoyment of Science Lessons is one scale from the TOSRA that was adapted by Aldridge and Fraser (2008) in a longitudinal study of outcomes-focussed learning environments and their determinants and effects in Western Australia. This scale was renamed Attitude to Subject and administered to 2317 students in 166 classes.

2.3.3 Academic Efficacy

Academic efficacy is associated with self-efficacy research and is supported by the work of Bandura (1977), which presents a theory that psychological procedures alter the level and strength of self-efficacy. Social theorists suggest that self-efficacy or belief and confidence in completing a task is important and can influence certain behaviours towards learning. High levels of self-efficacy can contribute to greater academic success (Lorsbach & Jinks, 1999; Multon, Brown & Lent, 1991; Pajares, 1996; Schunk, 1989). Bandura (1977) elaborates that self-efficacy is associated with a level of effort expended and whether coping behaviour will be initiated to accommodate obstacles or adverse behaviour. His model is underpinned by four principal sources of information: performance accomplishment, vicarious experience, verbal persuasion and physiological states. Schunk (1989) states that self-efficacy is an important construct that explains students' learning and performance in terms

achievement. Self-efficacy is influenced by a range of situational factors, such as perceived ability, task difficulty, effort expended, external assistance received, task outcomes, patterns of successes and failures and external influences both negative or positive (Bandura, 1977, 1982).

Whilst Fraser and Fisher (1994) claim that student perceptions can influence learning outcomes, the literature supports the theory that academic self-efficacy can also influence academic performance (Jinks & Morgan, 1999; Lorschach & Jinks, 1999; Schunk, 1996). Individuals with high academic self-efficacy approach tasks which are challenging and difficult with confidence and a positive mindset and are more likely to persist with the task (Pajares, 1996; Schunk 1991), whereas individuals with low academic self-efficacy are more likely to give up on difficult and challenging tasks (Zimmerman, 2000; Zimmerman, Bandura & Martinez-Pons, 1992).

Pajares, Britner and Valiante (2000) considered the difference between task and performance orientations in terms of approach tendency. They explain that task goals develop ability, whilst performance goals demonstrate that ability. Students can strive to attain success or avoid failure; hence motivation has both an approach tendency and an avoidance tendency. In other words, motivation and effort are influenced by an individual's academic self-efficacy (Schunk, 1996).

In a study of mathematics goal orientation, Middleton and Midgley (1997) reported that, for 703 grade 6 students, task goals were positively related with academic self-efficacy and self-regulated learning. Performance-avoidance goals were negatively related to self-efficacy and positively related to test anxiety. Usher (2009) reported that students with high mathematics self-efficacy had higher levels of achievement in mathematics, whilst students with low self-efficacy recounted their poor performance and struggles. The study explored the notion of 'mastery experience' as a powerful source for self-efficacy (Lent, Lopez & Bieschke, 1991).

The Morgan-Jinks student efficacy scale (MJSES, Jinks & Morgan, 1999) was designed to gather information regarding students' belief in their academic success. The MJSES is an extensive inventory that makes use of self-report grades as a dependent variable. The scale displayed sound validity and reliability and the final

version has 53 items. A Likert response scale includes Really Agree, Kind of Agree, Kind of Disagree, and Really Disagree. The relationship between self-efficacy beliefs and motivation has been well documented in past research when using the MJSES, with significant associations emerging between academic performance and academic self-efficacy (Jinks & Morgan, 1999; Pajares 1996, 2007).

Past research on learning environment has included many studies of associations between learning environment and self-efficacy (Aldridge & Fraser, 2011; Chionh & Fraser, 2009; Gupta & Fisher, 2012; Koul, Fisher & Shaw; 2011; Martin-Dunlop, 2016; Velayutham, Aldridge & Fraser, 2011). In these studies, a primary focus was to determine the extent to which the learning environment created by teachers was related to students' self-efficacy.

Aldridge and Fraser (2008) reported a major longitudinal study in which the MJSES was used as the basis for one scale for Academic Efficacy. The study reported statistically significant and positive associations between Academic Efficacy and all 10 TROFLEI scales at the individual level and with 9 TROFLEI scales at the class level. For Academic Efficacy, the learning environment scales which uniquely accounted for a significant proportion of variance were Involvement, Task Orientation, Investigation, Cooperation, Differentiation, Computer Usage and Young Adult Ethos at the individual level and Student Cohesiveness, Investigation, Cooperation, Equity, Differentiation and Young Adult Ethos at a class level. This scale is relevant to my study and is further discussed in Section 3.5.3

Dorman and Fraser (2009), in a study involving 4146 high-school students in Tasmania and Western Australia, investigated psychosocial environment and affective outcomes in technology-rich classrooms by testing a causal model. The study utilised 10 scales of the TROFLEI and the three student outcome measures of Attitude to Subject, Attitude to Computer Use and Academic Efficacy. A relationship between academic efficacy and classroom environment emerged, with significant positive correlations between Teacher Support, Involvement, Investigation, Task Orientation and Equity and Academic Efficacy. This study adds to the growing body of evidence supporting positive associations between learning environment and academic efficacy.

2.4 Sex-Related Differences

My study investigated the differential effectiveness of project-based mathematics for males and females in terms of learning environment, attitude, academic efficacy and achievement. This section provides a review of the literature related to the topic of sex-related differences in terms of learning environment and student outcomes.

Past research in this area has mainly focussed on a pattern of male superiority in mathematics and science achievement, but many studies suggest that this is age-related and that many other factors contribute to sex-related differences in student outcomes (Britner, 2008; Fennema & Sherman, 1978; Usher & Pajares, 2006). Indeed, the presence of sex differences is a result of social factors from the home and school environment. Young and Fraser's (1993) study of relationship between school environment and student performance revealed limited sex-related differences in and between classes and schools. In addition, there is a range of influences that cannot be discounted, including stereotyping of mathematics and science as a male domain, the attitudes of parents to these subjects, and confidence and usefulness of the subject (Fennema & Sherman, 1978).

Bandura (1977, p. 191) argues that a person's self-efficacy is influenced through four types of experiences namely, "performance accomplishment, vicarious experience, verbal persuasion and physiological states" with 'performance accomplishment' accounting for the greatest proportion of variance. Females reported that 'verbal persuasions' powerfully informed their academic and self-regulatory self-efficacy. This was supported by the work of Zeldin and Pajares (2000) who stated that, when forming self-efficacy beliefs, females relied more on other people's feedback and judgement, rather than 'performance accomplishment'. Erickson (1986) reported that schools play an important part with respect to self-efficacy of males and females. Males tended to develop their self-efficacy on the basis of 'mastery experience', accomplishments, good grades and feedback on successes or failures. For females, it is more about the messages that they receive from their teachers, parents and significant others about their accomplishments. Hence, high-quality feedback has an important place in building self-efficacy.

Ma and Cartwright (2003), in a longitudinal study on sex-related differences in affective outcomes in mathematics during middle and high school, reported three important mathematics affect outcomes, namely, attitude towards mathematics, anxiety towards mathematics and utility of mathematics. They found sex-related differences and a decline in all three outcomes for males and females. More specifically, female anxiety grew faster than male anxiety towards mathematics, although there was no sex-related difference in the decline in attitude to or utility of mathematics. A significant difference between males and females was found in understanding mathematics as a 'process-oriented' activity. Considering attitude and utility towards mathematics, sex-related differences were observed at the school level. No specific school-level variables explained the decline of female attitude and utility towards mathematics, but school context and school climate significantly predicted the male rate of decline towards mathematics. It implies that females develop their attitude to mathematics independently of school climate and context. Furthermore, sex-related differences for anxiety were small compared with sex-related differences in attitudes to mathematics.

Liu, Zandvliet and Hou (2012) investigated the perceptions of 2869 Taiwanese senior high school students of their Information Technology classrooms using the WIHIC, as well as the physical learning environment using the Computerised Classroom Environment Inventory (CCEI). This study sought understanding of the influence of different gender compositions in classes (mixed or single sex) on student perceptions of their classroom learning environment and satisfaction. They found that two scales of the CCEI, namely, Spatial Environment and Autonomy/Independence were strong indicators of student satisfaction and that the gender composition of classes resulted in quite different relationships between students' satisfaction, physical environment and psychosocial environment.

Peer and Fraser (2015) investigated sex, grade-level and stream differences in learning environment and attitudes to science in Singapore primary schools for a sample of 1081 students in 55 classes. Significant sex differences were found for Involvement, Teacher Support, Task Orientation and Cooperation, but effect sizes were relatively small (between 0.14 and 0.29 standard deviations). Statistically significant

stream-by-sex interactions for Task Orientation and Enjoyment were observed. More specifically, regarding Gifted Education and High Ability streams, High Ability male students scored higher for both Task Orientation and Enjoyment compared to Gifted Education male students, whilst Gifted Education female students scored higher for Task Orientation and Enjoyment compared to High Ability female students. In considering sex-related differences, the researchers reconsidered the findings in terms of the sex-stream interaction in order to clearly interpret the sex effect. In essence, females had higher Task Orientation scores compared with males in the Gifted Education stream but sex differences were negligible in the High Ability stream. In addition, whilst there was a negligible sex difference in Enjoyment in the Gifted Education stream, Enjoyment was higher in the High Ability stream for males than females.

Yang (2015) conducted a study of rural junior-secondary school students' perceptions of classroom learning environments and their attitude and achievement in mathematics. The study involved a sample of 2455 grades 7 to 9 students from 12 coeducational schools and 52 classrooms in three provinces in China. Using the WIHIC and the two scales of Confidence in Learning Mathematics and Usefulness of Mathematics from an attitude questionnaire (Fennema & Sherman, 1976), male and female students were found to perceive their classroom learning environment differently. Males tended to perceive involvement in mathematics and more opportunities to carry out inquiry activities as favourable, whilst females tended to perceive more student cohesiveness and opportunities to cooperate with others in the class more favourably.

In a study involving 312 boys and 185 girls in 18 secondary grade 10 chemistry classes from 3 independent schools in Singapore, Quek, Wong and Fraser (2005) investigated differences between boys' and girls' perceptions of their chemistry laboratory classroom environment using a modified version of the SLEI called the Chemistry Laboratory Environment Inventory (CLEI). Statistically significant sex-related differences were found for each CLEI scale, with the largest difference observed for the scale of Material Environment. For Rule Clarity and Material Environments, boys' perceptions of their laboratory environment were significantly less favourable than

girls' perceptions in terms of Material Environment. On the other hand, for girls, the level of Student Cohesiveness in a laboratory environment was perceived to be less favourable than for boys. Girls also preferred to have more Open-Endedness, Rule Clarity and Material Environment compared to boys. Overall the study reported that girls tended to perceive the laboratory environment just as favourably as boys.

Rogers (2013) investigated sex and frequency of practical work as determinants of middle-school science students' attitudes and aspirations using a modified version of the SLEI and scales from the Students' Adaptive Learning Engagement in Science (SALES). With a sample of 431 grades 9–10 students, the study revealed statistically-significant sex differences, with females reporting more positive perceptions of their laboratory learning environment than males. In terms of attitudes, Future Intentions and Self-Efficacy, males expressed more positive attitudes.

2.5 Project-Based Learning

My study involved the effectiveness of project-based mathematics in terms of learning environment, attitudes, academic efficacy and achievement for students in their first year of high school. It is important to understand the background to project-based learning in mathematics as a teaching approach compared with a more-traditional teaching approach (Section 2.5.1) and what features project-based learning entails (Section 2.5.2). A review of past studies involving project-based learning in terms of learning environment and student outcomes (Attitude, Efficacy and Achievement) is important in connecting the findings of my study with the research in this field (Section 2.5.3).

2.5.1 Project-Based Learning – Background

Project-based learning is a strategy which is significantly different from traditional classroom teaching. The benefits of this strategy have not been clearly established in secondary mathematics education (Petrosino, 2004; Strobel & Barneveld, 2009). Research suggests that students' choices are influenced by their attitudes towards and performance in mathematics, with these being shaped by their mathematical experiences at school (Nardi & Steward, 2003). Classroom environments in

secondary-school settings, particularly during the transition of students from primary to secondary school, are generally perceived less favourably by students because of changes in curriculum, pedagogy, assessment strategies, social interactions and student relationships (Attard, 2010).

It is suggested that changes from primary to secondary school in teaching strategies in mathematics and the role of the teacher could influence student perceptions of their learning environment (Ferguson & Fraser, 1998). Explicit teaching of mathematical concepts using a procedural strategy, in isolation from problem solving and reasoning, is common in a traditional secondary mathematics curriculum. Research also indicates that low-level procedural mathematics after transition can lead to a negative learning experience because students have generally achieved more-sophisticated levels of mathematics in primary school because of an integrated learning approach in the primary curriculum. This could lead to a loss of students' confidence in mathematics, an attitude of disengagement and a regression in academic progress compared with their primary-school experience (Attard, 2010).

Stacey (2010) states that research data continue to show trends which are characterised by a 'shallow teaching syndrome' and an absence of reasoning as a proficiency in grade 8 mathematics. A high percentage of problems in mathematics classes are close repetitions of previous primary-school problems with low procedural complexity. Lithner (2007) argues that, after 20 years of research, rote learning and procedural mathematics, rather than problem-based or project-based activities, continue to hamper student progress in higher-order thinking tasks. Self-regulated learning relies on learners having mastered the cognitive and motivational processes to steer their own learning outcomes (Velayutham, Aldridge & Fraser, 2011) and is critical in the success of project-based oriented learning.

A project-based mathematics learning strategy is defined as a research-based, open-ended and student-centred learning process, which is student-driven and teacher-facilitated (Bell, 2010). This instructional strategy can be effective in increasing learners' motivation and retention of information as they engage in higher-order thinking skills to achieve their tasks (Schwartz, Mennin, & Webb, 2001).

2.5.2 Features of Project-Based Learning

Project-based learning has been used in many different academic disciplines for well over 35 years. It evolved from the health sciences and was adopted in medical programs to better prepare students with real-life scenarios and was ultimately adopted across Northern American and European medical schools (Savery, 2006). When Albanese and Mitchell (1993) conducted a meta-analysis of 20 years of project-based evaluation studies, they concluded that a project-based approach was equally effective as a traditional approach in terms of conventional test results, but that students involved in project-based learning displayed better problem-solving skills.

A project-based mathematics learning strategy is focussed on engaging students using an instructional format that involves research, integrating theory and practice, applying skills and knowledge and working through tasks motivated by real-world projects which incorporate mathematical concepts (Bender, 2012; Savery, 2006). It features real-world projects involving an engaging question, problem or task which is often ill-defined, integrated across several disciplines, and connected with mathematical content in the context of working collaboratively with other students in a team (Barell, 2007, 2010; Baron, 2011; Grant, 2010). In summary, a project-based mathematics learning strategy engages students through a research-based, open-ended and student-centred learning process, which is student-driven and is teacher-facilitated (Bell, 2010).

A project-based strategy is often considered to be problem-based, inquiry-based or case-based approach. All these approaches have similarities, and as discussed above, in project-based learning, students are given clear instructions around specifications which lead to a final product which is submitted for assessment (Blumenfeld et al., 1991; Savery, 2006). Mosier, Bradley-Levine and Perkins (2013) state that there are many similarities between project-based and problem-based learning. A subtle difference is that a project-based approach is applied, procedural and solution focussed, whilst a problem-based approach is similar but it emphasises the learning process. Project-based learning is an instructional method which is suitable as an approach in the mathematics curriculum (Savery, 2006).

Research suggests that project-based mathematics enables students to be active participants in their own learning process and make meaningful connections between content and problem (Ahmad Tarmizi & Bayat, 2012).

The positive effects of project-based learning as a strategy in higher education have been well documented in various studies (Albanese & Mitchell, 1993; Coliver, 2000; Gijbels et al., 2005; Mergendollar, Maxwell & Belisimo, 2006). Increased levels of student engagement, higher levels of motivation, and student involvement with essential skills such as team work, collaboration, communication and research prepare them well for future life challenges (Bender, 2012). Research also suggests that the effectiveness of project-based learning is dependent on whether the curriculum involves real-world problems and emphasises cognitive skills and knowledge through a student-centred learning environment which utilises small groups (Drake & Long, 2009). Research into the effectiveness of project-based learning in a high-school context has been limited and inconclusive (De Witte & Rogge, 2012; Maxwell et al., 2001, 2005; Mergendollar et al. 2000).

2.5.3 Past Research on the Effectiveness of Project-based Learning

Research has been conducted into the effectiveness of project-based learning or problem-based learning (PBL) for well over 40 years primarily in the higher education sector in medicine, engineering, science and economics (Strobel & van Barneveld, 2009). Despite extensive research, there is considerable debate about the effectiveness of PBL. In the area of mathematics and specifically in the middle years, research is scarce. In a meta-synthesis of meta-analyses comparing PBL and traditional classrooms, Strobel and van Barneveld (2009) reported that PBL was effective in terms of long-term retention, skill development and satisfaction among participants, whilst traditional approaches were more effective for short-term retention particularly in tests and standard examinations.

Albanese and Mitchell (1993), in their studies in medical education, found a negative effect for project-based learning compared with a traditional approach. This was primarily for standardised tests and examinations, for which students in traditional classrooms performed better than those in PBL classrooms. They raised questions

about the forms of assessment used to measure knowledge and skills, which could favour a specific approach to learning such as traditional teaching.

Vernon and Blake (1993), in their 22 studies of health-related programs, reported that standardised tests favoured the traditional approach and produced better outcomes compared to a PBL approach; however, better outcomes for PBL students were observed in practical situations. Berkson (1993), in research involving 10 studies before 1993, found no evidence that a PBL approach resulted in better problem solving, knowledge or skills. When Colliver (2000) focussed on the credibility of claims that PBL is effective in terms of student outcomes and achievement, he reported no evidence that PBL improved students' knowledge base.

In more-recent research specific to education, Sungur and Tekkaya (2006) reported the effects of problem-based learning and traditional instruction on self-regulated learning. This involved 61 Turkish students in grade 10 in two classes, with one class following traditional (teacher-centred and textbook-oriented) instruction and the other class following a PBL approach focusing on ill-structured problems in biology. PBL students tended to participate more and be involved for reasons of challenge, curiosity and mastery. In addition, PBL students valued a student-centred approach, which includes research, problem challenge, group work and personal relevance. Whilst PBL students had a positive influence on students' goal orientation and task value, there was no evidence of a positive effect in the area of self-efficacy and performance. They reported that PBL students demonstrated a level of anxiety and concern about how a PBL approach might affect their preparedness for examinations. This was evidenced by a statistically nonsignificant higher score on anxiety among students in the PBL class compared to the traditional class. Importantly, the researchers reported that PBL students demonstrated higher levels of metacognitive self-regulation, use of elaboration strategies, critical thinking and peer learning compared with students in a traditional classroom.

Abdullah, Tarmizi and Abu (2010), in their study involving 53 senior-school students in Malaysia and concerning the effects of problem-based learning on mathematics performance and affective attributes in learning statistics in grade 10 reported no

significant performance differences between the two groups and that a PBL instructional strategy was just as effective as a traditional strategy. They also reported that both groups showed positive perceptions of group work, interest in the subject of mathematics (attitude) and perceptions of their learning experience. However, PBL students demonstrated more effective problem-solving procedures, displayed better communication skills and showed stronger team work compared with the traditional class.

In a study of the impact of project-based learning in STEM (Science, Technology, Engineering, Mathematics) in high-needs schools, Mosier, Bradley-Levine and Perkins (2013) conducted longitudinal research with 256 students in a mid-western state of the USA. They reported that increased use of PBL in classrooms was strongly associated with better outcomes for student engagement, positive classroom culture and interest in STEM. Importantly, they noted that demographic characteristics, timeframe and the teacher did not have a significant effect on the outcomes of the study.

De Witte and Rogge's (2012) study of problem-based learning in secondary education revealed similar findings to previous research in PBL. Their study involving 531 senior-secondary students from 15 schools, with 260 students grouped in PBL classes and 271 in traditional classes. PBL students' achievement scores were not significantly different from the scores of students in traditional classes. This result is consistent with other research in this field.

In terms of student motivation in PBL classes, there was a small positive effect across the whole sample, but females in PBL classes reported a lower level of motivation in comparison to females in traditional classes. In terms of PBL and classroom atmosphere, PBL students reported higher scores than students in traditional classes, but the improvement in classroom atmosphere was not because of the didactic nature of PBL, but rather because of the change to an alternative instructional strategy compared with the traditional classroom. Students viewed PBL as a welcome change from traditional classroom teacher-directed and textbook-oriented learning (De Witte & Rogge, 2012).

2.6 Summary

This chapter has outlined the growing body of research on learning environments, student attitudes, self-efficacy and achievement. These fields continue to grow across the world to include a much richer cross-cultural perspective as well as contributing to the extensive development and modification of learning environment instruments. Ongoing research in these fields is important in the continuous improvement of educational settings in order to maximise student outcomes and achievements.

My study involved the effectiveness of project-based mathematics in the first year of high school in terms of learning environments, attitude, academic efficacy and achievement. A detailed literature review was provided of previous and current research pertaining to learning environments (Section 2.2), attitude to subject, academic efficacy, sex-related differences and project-based learning (Sections 2.3.2, 2.3.3, 2.4 and 2.5). Section 2.2.1 reviewed the background to the field of learning environments from a historical and theoretical perspective and more specifically the origins beginning with the seminal works of Lewin (1936) and expanded by Murray (1938). Section 2.2.2 reviewed the development, validation and application of well-known classroom learning environment questionnaires beginning with the Learning Environment Inventory (LEI), the Classroom Environment Scale (CES), and the Individualised Classroom Environment Questionnaire (ICEQ). This was followed by the College and University Classroom Environment Inventory (CUCEI), the My Class Inventory (MCI), the Questionnaire on Teacher Interaction (QTI), the Science Laboratory Environment Inventory (SLEI), the Constructivist Learning Environment Survey (CLES), the Technology-Rich Outcomes-Focussed Learning Environment Inventory (TROFLEI) and the Constructivist-Oriented Learning Environment Survey (COLES).

Section 2.2.3 provided a more detailed review of the What Is Happening In this Class? (WIHIC) as this was the main learning environment instrument used in my study. Past research involving learning environment was covered in Section 2.2.4 with a particular emphasis on associations between student outcomes and classroom learning environment, evaluation of educational innovations, determinants of classroom

environment and the use of qualitative methods.

Section 2.3 contains a review on student attitudes, the Test of Science Related Attitudes (TOSRA) and the Morgan-Jinks Efficacy scale (MJSES) as scales from these instruments were used in my study. Sex-related differences were also covered in Section 2.4 as my study investigated the differential effectiveness of project-based mathematics for male and female students in terms of learning environment, attitudes, academic efficacy and achievement.

Section 2.5 provided background to project-based learning in mathematics, specifically in the transition from primary school to high school. The features of project-based learning were examined and project-based learning was defined. Past research into project-based learning and more recent research in STEM were covered. The next chapter includes the research methodology utilised in this study.

Chapter 3

RESEARCH METHODS

3.1 Introduction

In this study, I investigated the effectiveness of project-based mathematics for first-year high-school students in terms of learning environment, attitudes, academic efficacy and achievement. I also explored associations between students' perceptions of their learning environment, attitudes, academic efficacy and achievement, as well as the validity of the questionnaire used.

My research involved an explanatory mixed-method design (Creswell, 2008) for collecting multiple forms of data, including surveys, achievement tests, classroom observations and semi-structured interviews with students and staff (Kvale, 1996). Quantitative data were collected using the What Is Happening In this Class? (WIHIC) questionnaire, a modified scale (Attitude to Subject) from the Test of Science Related Attitudes (TOSRA) and the Morgan-Jinks Student Efficacy Scale (MSJES), which are all discussed later in this chapter. Students' achievement was assessed using a mathematics test, administered at the beginning and at the end of the study.

The research methods used in this study are outlined in this chapter in the following sections: the research methods (Section 3.2), the sample for the study (Section 3.3), quantitative data collection (Section 3.4), qualitative data collection (Section 3.5), data-analysis methods (Section 3.6), ethical issues (Section 3.7) and a chapter summary (Section 3.8).

3.2 Research Methods

This study utilised a mixed-method design which combined quantitative data from learning environment, attitude and achievement scales with classroom observations and student and teacher interviews. Creswell (2008) refers to the benefit of both quantitative and qualitative data working together to provide a better understanding of the research problem. The purpose of choosing this design was to build on the strengths of both quantitative and qualitative methods (Fraser, 1999), as well as compensating

for their weaknesses, in order to gain a deeper understanding of the outcomes of the study as well as the process of student learning from the perspective of the student and the teacher (Tobin & Fraser, 1998). This provides a 'powerful mix' and 'a more comprehensive' picture of my study (Greene & Caracelli, 1997; Miles & Huberman, 1994) by presenting an objectively-measured approach and exploration and explanations of the data through a qualitative view of reality through the lens of the student and teacher experience.

In this study, I utilised an explanatory mixed-methods design (Creswell, 2008; Creswell & Plano Clark, 2007) in two phases, with quantitative data collection in phase 1 being the primary approach. This was followed by a smaller qualitative component in the second phase of the study, aimed at better understanding and explaining the results from the quantitative data (Houtz, 1995; Ramlo, 2016).

3.3 Sample

The sample for the study involved a total of 284 students from a Catholic high school in metropolitan Adelaide, South Australia. The study included a cohort of students in their first year of high school, consisting of a project-based group of 192 students (91 males and 101 females) in seven classes and a comparison group of non-project based learning in three classes with 92 students (47 males and 45 females).

The participants in their first year of high school came from primary schools across three sectors of education, namely, the government school sector (34%), Catholic school sector (58%) and independent school sector (8%). A socio-economic status index (SES) is an economic, sociological combined total measure of a school's economic and social position in relation to families, based on income, education, home address and occupation. The research school has an index of 91 and is categorised at the upper end of the disadvantaged schools category (ABS, 2008). The students in this study came from 32 primary schools, where the average numeracy levels for students were below the Australian national average standards in the National Assessment Program for Literacy and Numeracy (ACARA, 2012).

At the time of my study, the high school had been involved in project-based learning

for three years. A project-based method has been integrated into the school's curriculum in subjects such as Geography, History, Environmental Studies, Science and Mathematics. The school authorities were interested in the effectiveness of project-based learning and sought interest from different faculties to be part of this research. The staff of the mathematics faculty unanimously agreed to be involved in this study and the school authorities sought support and permission from the parent body and school governing council. The teachers of ten mathematics classes volunteered and permission was sought from students and parents. Participation in the study was voluntary and involved students over a period of six months. Seven teachers and their classes nominated for the project-based approach and three teachers nominated their classes as a comparison sample following a traditional non project-based approach, which was the standard teaching method used at the school. Table 3.1 provides a breakdown of the final number of students and classes in this study for the project-based and traditional approaches.

Table 3.1 Description of Whole Sample

Class	Group	Students		
		Male	Female	Total
1	Project	11	17	28
2	Project	14	15	29
3	Project	11	15	26
4	Project	13	13	26
5	Project	15	13	28
6	Project	15	14	29
7	Project	12	14	26
Total		91	101	192
8	Non-project	16	14	30
9	Non-project	15	15	30
10	Non-project	16	16	32
Total		47	45	92
Grand Total		138	146	284

Observations were conducted in the latter part of the study and interviews were conducted with students and staff after the conclusion of the study. Observations were conducted in four out of the seven project-based classes, with teachers volunteering for this phase. In addition, three teachers who taught the project-based classes volunteered to be interviewed from the sample of 7 project-based classes. For the student interviews, the teacher of every class was asked to provide a sample of 4 volunteer students (two male and two female). Therefore, seven student groups were interviewed. Details of the administration and management of data are explained in Section 3.4.5, and limitations of the sample are considered in Chapter 5.

3.4 Quantitative Data Collection

Quantitative data collection involved instruments that assessed the learning environment and the student outcomes of attitudes and achievement. These instruments were chosen because of the relevance to my study, in terms of alignment with the research questions and because they have been extensively validated and used in similar past studies. The WIHIC was chosen because its seven scales capture salient features of the classroom climate and it has established reliability and validity (Dorman, 2003, 2008; Fraser, 2014; Zandvliet & Fraser, 2004, 2005). The WIHIC was discussed extensively in Section 2.2.3 and is further discussed in Section 3.4.1 below.

To investigate student attitudes, two scales were used. Attitude to Subject was modified from the Test of Science-Related Attitudes (TOSRA) and Academic Efficacy was based on the Morgan-Jinks Self-Efficacy Scales (MJSES). The TOSRA was described in Section 2.3.2 and the MSJES was covered in Section 2.3.4. A mathematics test described in Section 3.4.3 was used to gather achievement data. The next section provides a description of both of these instruments and explains the development of the achievement test.

3.4.1 What Is Happening In this Class? (WIHIC) Questionnaire

The WIHIC questionnaire was developed by Fraser, Fisher and McRobbie (1996), and has been extensively used in the field of learning environments. It has been widely reported in past studies that the WIHIC has been reliable, valid and useful in different subject areas, age groups and countries (Aldridge & Fraser, 2000, 2008; Aldridge, Fraser & Huang, 1999; Chionh & Fraser, 2009; Martin-Dunlop & Fraser, 2008). The WIHIC has also been successfully used in a significant number of studies involving junior high-school students (Aldridge & Fraser, 2000; Aldridge et al., 1999; Dorman, 2003; Dorman et al., 2003; Kim et al., 2000). Studies by Earle and Fraser (2016), Ogbuehi and Fraser (2007) and Opolot-Okurut (2010) successfully used the WIHIC with junior high-school students in mathematics. The WIHIC has also been used successfully in previous studies of the impact of innovative new learning strategies in terms of student perceptions of their learning environment (Martin-Dunlop & Fraser, 2008; Ogbuehi & Fraser, 2007; Wolf & Fraser, 2008; Yang, 2015). The WIHIC and its use in past studies of learning environment were reviewed extensively in Section 2.2.3 and Section 2.2.5, respectively.

In order to assess students' perceptions of the classroom learning environment during the project-based learning experience, the 56-item seven-scale WIHIC was used as a pretest and a posttest. The WIHIC's scales are Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity. Each scale has eight items and is measured on a 5-point frequency scale ranging from Almost Never to Almost Always. Table 3.2 provides a summary of the scale name, a scale description and sample item for each scale of the WIHIC (Fraser, Fisher & McRobbie, 1996).

The objective of the study was to investigate the effectiveness of project-based mathematics and therefore ascertain whether any changes in students' perceptions of their learning environment occurred as a result of their mathematical experience during the trial period. The personal form of the instrument was used to gather the students' perceptions of their individual role in the classroom rather than students' perceptions of the class as a whole. Because project-based mathematics has a strong constructivist

orientation, the personal form was more suitable for my study, in accordance with constructivist theory (Aldridge & Fraser, 2008).

The Student Cohesiveness scale is described as the extent to which students know, help and are supportive of one another. An example of one of the items is “I work well with other class members”. This scale was centrally relevant in my study because many of the project-based activities require students to work in small groups. Teacher Support measures students’ perceptions of the extent to which the teacher guides and is interested in students. Because much of the project-based activity requires groups to work independently, the teacher assumes a facilitator role, which is different from the traditional role of the teacher. Involvement, Investigation, Task Orientation and Cooperation are scales which are intimately connected to the nature of students’ work in project-based mathematics. Equity measures the extent to which a teacher treats students equally, including distributing praise, answering questions and providing opportunities for students to be included in conversations. This is associated with the unique role of the teacher in this new innovative strategy, which requires the teacher to work with different groups and ensure that groups work collaboratively and in harmony. The teacher encourages students to be focussed on the task and assists them in their own learning.

In order to limit response bias and prevent passive responses in past studies, negatively-worded items sometimes have been used (Aldridge & Fraser, 2008; Velayutham et al., 2011). However, past studies have reported that positively-worded items have demonstrated better response accuracy and are less confusing to junior high-school students (Schreisheim, Eisenbach & Hill, 1991). In my study, I ensured that the items in each scale were positively worded. Finally, the 5-point frequency response scale used included Almost Never, Seldom, Sometimes, Often and Almost Always. A copy of the WIHIC questionnaire is provided as Appendix A.

Table 3.2 **Scale Description and Sample Item for Each WIHIC Scale**

Scale	Scale Description	Sample Item
	<i>The extent to which ...</i>	
Student Cohesiveness	Students know, help and are supportive of another.	I work well with other class members.
Teacher Support	The teacher helps, befriends and is interested in students.	The goes out of his/her way to help me.
Involvement	Students have attentive interest, participate in discussions, do additional work and enjoy the class.	I explain my ideas to other students.
Investigation	Emphasis is placed on the skills and processes of inquiry and their use in problem solving and investigation	I explain the meaning of statements, diagrams and graphs
Task Orientation	It is important to complete activities planned and to stay on the subject matter	I know what I am trying to accomplish in this class
Cooperation	Students cooperate rather than compete with one another on learning tasks.	When I work I work with other students on projects in this class.
Equity	Students are treated equally by the teacher	The teacher gives as much attention to my questions as to other students' questions.

Adapted from Aldridge and Fraser (2008) – with permission

3.4.2 Assessing Student Attitudes

In Section 2.3, it was explained previously that, in line with a precedent set in past studies, I subsumed the construct of ‘academic efficacy’ under the general label of ‘attitude’ in order to achieve economy and parsimony in reporting. Therefore, this section devoted to how I assessed student attitudes in my study encompasses scales for assessing both attitude to subject (Section 3.4.2) and academic efficacy (Section 3.4.2).

In order to assess attitudes in my study, I drew on two scales, namely, Attitude to Subject which is a modified version of Enjoyment of Science from the Test of Science-Related Attitudes (TOSRA; Fraser, 1981) and the Academic Efficacy scale which is based on the Morgan-Jinks Student Efficacy Scale (Aldridge & Fraser, 2008; Jinks & Morgan, 1999). Given that a strong relationship between learning environment and student outcomes has been reported in many past studies (Aldridge & Fraser, 2008; Fraser, 2014; Zandvliet & Fraser, 2004, 2005), attitude and self-efficacy can be important dependent variables in classroom learning environment studies (Lorsbach

& Jinks, 1999). Numerous past studies have incorporated the WIHIC together with one or two scales from the TOSRA (Cohn & Fraser, 2016; Long & Fraser, 2015; Martin-Dunlop, 2016; Ogbuehi & Fraser, 2007). Because project-based mathematics was a new strategy for engaging students in higher-order thinking and challenges to problems at the school involved in the study, rather than a traditional routine and mathematical-process oriented approach, it was important to measure how much students enjoyed their mathematics classes. Use was made of Aldridge and Fraser's (2008) eight-item Attitude to Subject scale which was adapted from the TOSRA, which has the same 5-point frequency response as the WIHIC (Almost Never, Seldom, Sometimes, Often and Almost Always). See Section 2.3 for a detailed review of research on student attitudes.

The second scale (Academic Efficacy) used was an adapted version of the Morgan Jinks Student Efficacy Scale (MJSES) developed by Jinks and Morgan (1999). Past studies and research have emphasised the importance of student self-efficacy as central to improving student outcomes and achievement (Bandura, 1982, 1989; Schunk, 1989; Zimmerman, Bandura & Martinez-Pons, 1992). The aim of project-based mathematics is for students to be more-deeply engaged with challenging problems and higher-order questions and solutions. Because Pajares (1996) reports that high-efficacy students are more likely to engage in a broader range of strategies and process higher levels of information, this scale was ideal for measuring Academic Efficacy and its association with learning environment. Academic Efficacy has the same 5-point frequency response scale as the WIHIC. See Section 2.3.3 for a detailed review of Academic Efficacy. Table 3.3 provides a description and sample item for the two attitude scales used in my study. A copy of the Attitude Questionnaire is provided in Appendix A.

Table 3.3 Scale Description and Sample Item for the Attitude to Subject and Academic Efficacy Scales

Scale	Scale Description	Sample Item
Attitude to Subject	The extent to which students enjoy lessons in this subject.	I look forward to lessons in this subject.
Academic Efficacy	Students' belief about their academic competence.	I find it easy to get good grades in this subject.

Adapted from Aldridge and Fraser (2008) – with permission

3.4.3 Assessing Student Achievement

In order to evaluate the effectiveness of the project-based mathematics strategy in terms of student achievement, a multiple-choice achievement test was developed with guidance from the Australian national standards for Year 7 students (ACER, 2013). The test consisted of 38 multiple-choice questions, which assess mathematical skills and knowledge within the areas of numbers, space, measurement, chance and data, and algebra. This test was administered as a pretest in the sixth week of the academic school year to determine the students' initial level of achievement. A similar achievement test developed to the Australian national standard for Year 8 (first-year high school in South Australia) was administered six months later as a posttest following the completion of the innovative mathematics strategy. A sample copy of the posttest is provided in Appendix B. The tests were used to evaluate student progress in terms of mathematical competence during the study. Achievement tests have been successfully used in past studies of the effects of learning environment (Cohn & Fraser, 2016; Holding & Fraser, 2012; Rita & Martin-Dunlop, 2011; Spinner & Fraser, 2005; Wolf & Fraser, 2008; Yang, 2015).

3.4.4 Administration of the Survey

The pretest questionnaire based on the seven scales of the WIHIC, the modified Attitude to Subject scale from the TOSRA and the Morgan-Jinks Self Efficacy scale was administered in the sixth week of the first term of the academic year, after students in the sample had the opportunity to establish themselves in their new learning environment and become familiar with their teachers. The posttest questionnaire was administered six months into the study.

Each student who had permission to participate in the study was given a unique identifier in order to match pretest and posttest data and to maintain confidentiality. The questionnaire was designed to be administered online, using a school-based survey tool for ease of administration and to ensure that students completed the questionnaire in full. The on-line version of the questionnaire did not permit a student to continue through the questionnaire unless each question had been answered. Partially-completed surveys were discarded. This provided a high level of accuracy. A total of

only 22 out of a possible 214 surveys were discarded from students in the project-based trial who had completed either a pretest or a posttest, but not both. A total of 13 out of a possible 105 surveys were discarded from students in the comparison classes as a result of completing either a pretest or a posttest, but not both.

The permission rate for participation in this study was very high at 98% (214 out of 218 students in project-based classes), reflective of the commitment by the school leadership and staff in explaining the benefits of participating in the project and collecting consent forms. The questionnaire was administered by the researcher so that students could respond in confidence and not feel pressured about answering the questionnaire with their teacher present. Final data were gathered into a spreadsheet file and uploaded into the Statistical Package for the Social Sciences (SPSS) version 19.0.

3.5 Qualitative Data Collection

Previously in Section 3.4, it was established that the primary data-collection method for this study was the administration of questionnaires with scales that assess students' perceptions of their learning environment and their attitudes, efficacy and achievement to mathematics. As recommended by Tobin and Fraser (1998), this research included a minor qualitative data-collection component involving observations and interviews, in an attempt to explain, embellish and triangulate the quantitative data.

Because the study involved the effectiveness of project-based mathematics, providing qualitative data could illuminate possible trends and explanations for the quantitative findings and enable the quantitative questionnaire data to be triangulated, clarified and explained. Houtz (1995), in her article "Instructional Strategy Change and the Attitude and Achievement of Seventh and Eighth-Grade Science Students" reported using an explanatory design. Observations and interviews with students and staff were used to explain the quantitative learning environment, attitude, efficacy and achievement data in answering the research questions in my study.

Interviews were conducted with a random sample of 28 (14 male and 14 female) students from all of the seven project-based classes, randomly selected from a list of

volunteers and ensuring a gender balance from each project-based class. Classroom observations were conducted in four project-based mathematics classes during the study in order to record student engagement in project-learning tasks, with a particular focus on the seven scales (Teacher Support, Involvement, Student Cohesiveness, Task Orientation, Cooperation, Investigation and Equity) of the WIHIC. In collecting and analysing qualitative data, I was guided by Erickson (2012).

3.5.1 Interviews with Students

In order to provide the necessary data for the explanatory analysis, focus-group interviews (Kvale & Brinkmann, 2008) were conducted with students at the conclusion of the study in order to clarify their responses to the questionnaires and to provide additional insights into the project-based learning experience. Seven groups of four students (two males and two females) from each of the project-based classes were interviewed to provide explanations for the findings of the quantitative phase. Students were asked to volunteer in each class as a group of four, with a gender balance and students being randomly selected. Each group interviewed was given a code to distinguish between groups and each student in the group was given a sub-code for the purposes of managing the qualitative data. There was no matching of these students with their survey data. The focus-group interviews were conducted in a semi-structured format (Creswell, 2008; Laforgia, 1988). In addition, questions were asked to clarify classroom observations and to give deeper insight into students' engagement with the project-based activities and their attitude to mathematics. The lists of questions followed a standard format. The semi-structured nature of the interviews allowed a degree of flexibility in terms of expanding and elaborating on differences in the seven project-based classes. Each interview lasted for 40 minutes and interviews were digitally recorded. A copy of the interview questions can be found in Appendix C.

3.5.2 Interviews with Staff

A semi-structured one-on-one interview (Kvale & Brinkmann, 2008) was conducted with three out of the seven mathematics teachers from the project-based classes in order to address Research Questions 2 and 3, and to seek teachers' comments and

overall reflections on the project-based trial. This provided an opportunity to clarify the student questionnaire data from the teachers' perspectives, especially the effectiveness of a project-based mathematics strategy in terms of the learning environment and student outcomes. These interviews were conducted at the conclusion of the study. A standard list of questions for the teacher interviews was used for consistency reasons; however, the semi-structured nature allowed the flexibility needed to expand and elaborate on differences as experienced in their project-based classes. Each interview lasted 40 minutes and interviews were digitally recorded. A copy of the interview questions can be found in Appendix C.

3.5.3 Classroom Observations

Classroom observations were conducted in four of the project-based mathematics classes. When teachers involved in the project-based strategy were asked if the researcher could observe their classes, four teachers volunteered. These observations occurred midway through the study and again towards the end of the study. The purpose of the observations was to gather first-hand data about students' engagement in the learning environment in terms of the different constructs assessed by the questionnaire (Carpenter et al., 1989; Creswell, 2008). The researcher assumed a participant-observer role (Creswell, 2008, p. 222), which allowed direct participation in the task with student groups during program delivery. The researcher did not interfere in the classroom management in order for the locus of control to remain with the teacher. Descriptive and reflective field notes were generated (Creswell, 2008, p. 224). A copy of the observation template for classroom observation is provided in Appendix D.

All interviews were transcribed and uploaded into NVivo version 10. The benefit of using NVivo software was the ease of uploading text (transcripts), the ability to categorise data using the scales of the questionnaire, and the facility to assign codes for analysis purposes and for sorting the data (Creswell & Maietta, 2002).

3.6 Data Analyses

To answer the four research questions delineated in Section 1.4.1, quantitative and

qualitative data were collected and carefully analysed. This section details the methods used to analyse the data to answer each research question.

3.6.1 Research Question 1: *Is it possible to modify and validate a questionnaire based on the WIHIC and attitude and efficacy scales for use with first-year high-school students in Adelaide, South Australia?*

Given that a WIHIC and attitude and efficacy scales in this study had not been used previously in South Australia, it was necessary to check that they were valid and reliable. The data collected from 284 students were used to examine the factorial validity, scale reliability (alpha reliability coefficient) and ability to differentiate between classes (ANOVA). To examine the internal structure of the 56-items of the 7-scale WIHIC, I used principal axis factoring with varimax rotation and Kaiser normalisation, separately for the pretest and posttest data, for the sample of 284 students. The criteria used for retaining any item of the WIHIC were that it must have a factor loading of at least 0.40 for its *a priori* scale and a factor loading of less than 0.40 for each other scale. The individual student was used as the unit of analysis. Items that did not meet the criteria above were removed.

In order to examine the internal structure of the 16 items of the attitude/efficacy scales, I conducted a similar principal axis factoring with varimax rotation and Kaiser normalisation separately for pretest and posttest data for the sample of 284 students. Again, the criteria for the retention of any item were that it must have a factor loading of at least 0.40 on its *a priori* scale and less than 0.40 with every other scale in the same questionnaire, with items not meeting the criteria being removed.

In considering whether factors were interrelated, an oblique rotation in exploratory factor analysis was completed for both pretest and posttest. A relatively low correlation would suggest relatively little overlap of one scale with other scales and would compare favourably with other discriminant validity studies involving the WIHIC.

To examine the extent to which items in the same scale measure the same aspect, the reliability for each revised WIHIC, attitude and efficacy scale was estimated for two units of analysis (the student and the class mean). The internal consistency reliability

of each scale was calculated separately for pretest and posttest data using Cronbach's alpha coefficient. A reliability coefficient of 0.7 is deemed satisfactory and a value of 0.8 is considered as good (Cohen, 1988).

An analysis of variance (ANOVA) for each learning environment scale, for both the pretest and posttest and with class membership as an independent variable, enabled an examination of whether each WIHIC scale could differentiate between the perceptions of students in different classrooms.

3.6.2 *Research Question 2: Is Project-based Mathematics Effective for First-year High-school Students in terms of Learning Environment, Attitude, Academic Efficacy and Achievement?*

Research Question 3: Is Project-based Mathematics Differentially Effective for Females and Males in terms of Learning Environment, Attitude, Academic Efficacy and Achievement?

The second research question involved differences between the project-based group and non-project based group in terms of learning environment, attitude, efficacy and achievement scales. The third research question involved whether any differences existing between instructional methods were similar or different for female and male students.

Both of these two research questions were investigated simultaneously by conducting a two-way MANOVA with the whole sample of 284 students and with the seven WIHIC scales and two attitude/efficacy scales and one achievement scale as a set of 10 dependent variables. If the multivariate test yielded statistically significant results in terms of Wilks' lambda criterion, univariate two-way ANOVA would be interpreted for each individual scale. In addition, effect sizes (as recommended by Thompson, 2001) were calculated to provide an indication of the magnitude of differences between pretest and posttest. Cohen's *d* effect size is the difference between the means of two groups divided by pooled standard deviation of the two groups. The effect size conveniently expresses a difference between two groups in standard deviation units. According to Cohen (1988), effect sizes range from small (0.2) to medium (0.5) to large (0.8).

The pretest and posttest data for learning environment and student outcome scales collected from 284 students in 10 classes were used to investigate the differential effectiveness of project-based mathematics for males and females. A two-way MANOVA with repeated measures was used to identify the differential effectiveness of using project-based mathematics for males and females. The criterion for identifying differential effectiveness of using project-based mathematics was the presence of a statistically-significant occasion (pretest–posttest) \times sex (male–female) interaction. The independent variables for the two-way MANOVA was the testing occasion (pretest and posttest) and sex (male and female) and the dependent variables were the seven learning environment scales, two attitude/efficacy scales and achievement.

3.6.3 *Research Question 4: Are there Associations between the Learning Environment and Attitude, Academic Efficacy and Achievement?*

Simple correlation and multiple regression analyses were conducted using the whole sample ($N = 284$) to explore associations between the seven learning environment scales of the WIHIC and attitude/efficacy scales and achievement using the posttest data. Simple correlation was suitable for examining the bivariate relationship between each of the student outcomes and each learning environment scales. Multiple regression analysis provided information about the multivariate association between each of the student outcomes and the set of 7 learning environment scale, thus providing a more-conservative picture of the influence of the correlated learning environment dimensions on outcomes and reducing the Type I error rate associated with a simple correlation analysis. The standardised regression coefficients were used to identify which learning environment scales contributed uniquely and significantly to the degree of variance in the attitude/efficacy and achievement scales when the other learning environment scales were mutually controlled.

3.7 Ethical Issues

Research was conducted in accordance with the requirements in the National Statement of Ethical Conduct in Human Research (NHMRC, 2007) and by Curtin University, including the ethical protocols of Information, Permission, Privacy and

Confidentiality, Consideration and Acknowledgement (Howitt, 2008).

3.7.1 Information

Personal contact was established with the research school to explain the research to school authorities and teachers. Discussions were held with the Heads of Faculty and the research proposal was presented. Four faculties volunteered to be part of the study and, in consultation with the leadership team and Head of Curriculum, the Mathematics faculty was chosen as the focus of my study. In terms of information, a detailed information sheet tailored to the participating school was produced to clarify the aims of the research, the position of the researcher and how the results would be used. An information sheet and consent forms were produced for teachers, students and parents (Appendix E). Teachers explained that participation was voluntary and that non-participation would not have any impact on student grades.

3.7.2 Permission

In terms of permission, Curtin University ethics approval was received from the Curtin University Human Research Ethics Committee; a copy of the approval document is provided in Appendix G. Approvals were also obtained from the governing council of the research school and the school's leadership team. Written consent forms were produced and consent was sought from the parents/guardians of those students who volunteered to be involved in my study (Appendix F). Additional consent was sought from those participants involved in the interviews and, when students were involved, a school-based teacher was present during interviews. Participants were made aware that they could withdraw from the study at any time.

3.7.3 Privacy and Confidentiality

The anonymity of participants was maintained throughout the study by allocating a unique identifier number to each participant. This allowed matching of the pretest and posttest data. Classes involved in the study were not identified other than through a numerical code which enabled comparison of results across classes and the school. During observations, the researcher observed and rated interactions in the learning

environment and looked specifically for student behaviours and interaction with tasks in relation to the learning environment scales included in this study. Data from interviews were not associated with any names and, instead, identifier codes were used for the classes. During observation and interviews, the confidentiality of class, teacher and students was maintained. Video recording was not used during observations, but digital audio recording was used during interviews.

3.7.4 *Consideration and Acknowledgement*

Consideration was achieved by ensuring that the administration of the questionnaire at the beginning of the study involved consultation with the participating school and teachers and at a time convenient to the school. The questionnaire was administered in the morning (before students became tired and distracted from their learning) and in one 45-minute lesson (which was ample time to explain the procedures and gather the data). This fitted into the normal routine of a school with consideration being given to that the data collection not disrupting student learning or class dynamics. Interviews with students were conducted during their mathematics classes, following mutual agreement with the teacher and students. Interviews were conducted in a small room in the school's library. Interviews with teachers were held at a time convenient to the teacher. In terms of the observations, the researcher ensured full cooperation with little interference into class routine. At the conclusion of the study, the participants were officially acknowledged and a letter of appreciation was presented to the school authorities.

3.8 Summary

This chapter described the research methods used in my study, including the sample, the instruments used in the data-collection phase, the procedures for administration of the survey, the methods used to collect data in the qualitative phase of my study, and the data-analysis techniques for answering each of the research questions.

Because I investigated the effectiveness of project-based mathematics as part of wider school-based focus on project-based learning in the curriculum, involving a whole cohort at a particular year level as the research sample was considered appropriate by

the research school. The sample involved 192 students in 7 project-based classes and 92 students in 3 comparison classes from a co-educational high-school in South Australia. As the mathematics curriculum and teaching method in high school usually is formal and traditional in South Australia, the first-year of high school was chosen as the sample, which meant that the sample group had not been exposed to a traditional high-school mathematics experience for the purposes of this study. Given that similar studies of the effectiveness of innovative teaching strategies have used the WIHIC, I used the seven scales of the WIHIC coupled with two attitude scales, namely, Attitude to Subject (a modified scale from the TOSRA) and an adapted version of the Morgan-Jinks Efficacy scale. Achievement data were also collected using a 38-item multiple-choice test measuring mathematical skills and knowledge. Data were collected at the commencement of the study and at the conclusion of the study.

As the survey instrument had not been previously used in high schools in South Australia, statistical interrogation involved principal axis factor analysis with varimax rotation and Kaiser normalisation to determine the factorial validity of the WIHIC and the Attitude to Subject and Academic Efficacy scales. For each of the scales, the Cronbach alpha reliability coefficient was used as an index of scale internal consistency. In determining discriminant validity, an oblique rotation in exploratory factor analysis was undertaken for both pretest and posttests in order to investigate any scale overlap. In addition, an analysis of variance (ANOVA) for each learning environment scale, for both the pretest and posttest and with class membership as an independent variable, was undertaken to examine whether each WIHIC scale could differentiate between the perceptions of students in different classrooms.

To investigate the effectiveness of project-based mathematics and to determine whether project-based mathematics was differentially effective for female and male students, a two-way MANOVA was conducted with the seven WIHIC scales, two attitude/efficacy scales and one achievement scale as dependent variables. If the multivariate test yielded statistically significant results in terms of Wilks' lambda criterion, the univariate two-way ANOVA would be interpreted for each individual scale. A statistically significant instruction-by-sex interaction would indicate differential effectiveness and this is reported in Section 4.3.4. In addition, effect sizes

were calculated to provide an indication of the magnitude of differences between project and non-project groups for each learning environment and student outcome measure.

Simple correlation and multiple regression analyses were conducted to explore associations between students' perceptions of the learning environment and students' attitudes and achievement. Simple correlation provided information about the bivariate relationship between each of the student outcomes and each learning environment scale. Multiple regression analysis provided information about the multivariate association between each of the student outcomes and the set of 7 learning environment scales.

A minor qualitative data-collection component based on classroom observations, student and teacher interviews was used to explain, embellish and triangulate quantitative data. Qualitative data could illuminate possible trends and provide an explanation for quantitative findings by means of an analysis of themes, as reported in Section 4.5.

The next chapter reports in detail the data analyses and findings of my study.

Chapter 4

ANALYSES AND FINDINGS

4.1 Introduction

The primary purpose of this study was to determine the effectiveness of project-based mathematics in terms of learning environment, attitudes, academic efficacy and achievement for students in their first year of high school. A modified questionnaire based on the seven scales from the WIHIC (Fraser, Fisher and McRobbie, 1996), one attitude scale from the TOSRA (Aldridge & Fraser, 2008; Fraser, 1981) and the Morgan-Jinks student efficacy scale (Aldridge & Fraser, 2008; Jinks & Morgan, 1999) was administered at the beginning and conclusion of the study. Achievement data were also collected at the beginning and conclusion of the study using a school-based achievement test. Data were gathered from first-year high-school students ($N=284$) in seven project-based classes and three comparison classes in a co-educational high school in metropolitan Adelaide, South Australia. During my study, classroom observations were completed in project-based classes and interviews were conducted with students and staff from the project-based classes.

This chapter is dedicated to describing the data analyses and discussing the findings from the quantitative and qualitative data to answer four research questions as follows:

1. Is it possible to modify and validate a questionnaire based on the WIHIC and attitude and efficacy scales for use with first-year high-school students in South Australia?
2. Is project-based mathematics effective in terms of first-year high-school students' learning environment, attitudes, academic efficacy and achievement?
3. Is project-based mathematics differentially effective for females and males in terms of learning environment, attitudes, academic efficacy and achievement?
4. Are there associations between dimensions of learning environment and attitudes, academic efficacy and achievement?

The findings from the analyses of the survey data are reported in the following sections

of this chapter: the validity and reliability of the modified questionnaire drawn from the WIHIC (What Is Happening In this Class?), modified TOSRA (Test of Science Related Attitudes) scale and Morgan-Jinks efficacy scale (Section 4.2); differences between instructional methods and differential effectiveness of instructional methods for females and males (Section 4.3); associations between learning environment dimensions and student outcomes (Section 4.4); using qualitative data to explain survey findings (Section 4.5); and chapter summary (Section 4.6).

4.2 Validity and Reliability of the WIHIC and Attitude/Efficacy Questionnaire

Given that the WIHIC and attitude and efficacy scales of the modified questionnaire have not been previously used in Adelaide, South Australia to address the research questions, it was necessary to check whether the questionnaire was valid and reliable when used with this population. Therefore the data collected from 284 students were used to examine the factorial validity, scale internal consistency (alpha reliability coefficient), discriminant validity and ability to differentiate between classes.

4.2.1 Factor Structure of the WIHIC

My first research question focussed on the validity of the survey. To examine the internal structure of the 56 items of the seven-scale WIHIC (assessing Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity), I conducted principal axis factoring with varimax rotation and Kaiser normalisation separately for pretest and posttest data for the sample of 284 students. The criteria for the retention of any item were that it must have a factor loading of at least 0.40 for its *a priori* scale and less than 0.40 with every other scale in the same questionnaire. The application of these criteria led to the removal of one item from Student Cohesiveness (Item 6) and two items from Involvement (Items 21 and 23). After removal of these three items, the *a priori* seven-scale structure of the WIHIC was replicated perfectly. Table 4.1 shows the factor loadings obtained from the WIHIC (7 scales) using the student as the unit of analysis, together with the percentage variance and eigenvalues for each scale for the pretest and posttest.

Table 4.1 Factor Analysis Results for the Modified WIHIC for Pretest and Posttest

Item	Factor Loading													
	Student Cohesiveness		Teacher Support		Involvement		Investigation		Task Orientation		Cooperation		Equity	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	0.60	0.77												
2	0.52	0.54												
3	0.41	0.58												
4	0.79	0.82												
5	0.50	0.50												
7	0.76	0.75												
8	0.48	0.53												
9			0.77	0.75										
10			0.83	0.72										
11			0.69	0.79										
12			0.73	0.65										
13			0.73	0.78										
14			0.74	0.69										
15			0.74	0.60										
16			0.66	0.52										
17					0.70	0.82								
18					0.81	0.88								
19					0.51	0.62								
20					0.64	0.72								
22					0.49	0.61								
24					0.65	0.40								
25							0.65	0.87						
26							0.47	0.56						
27							0.68	0.91						
28							0.62	0.81						
29							0.74	0.88						
30							0.79	0.80						
31							0.75	0.75						
32							0.61	0.74						
33									0.65	0.67				
34									0.73	0.83				
35									0.59	0.64				
36									0.66	0.64				
37									0.70	0.71				
38									0.61	0.66				
39									0.60	0.71				
40									0.73	0.76				
41											0.61	0.65		
42											0.71	0.68		
43											0.61	0.77		
44											0.82	0.85		
45											0.71	0.79		
46											0.78	0.79		
47											0.46	0.68		
48											0.57	0.68		
49													0.62	0.81
50													0.58	0.79
51													0.79	0.83
52													0.80	0.83
53													0.79	0.85
54													0.78	0.82
55													0.68	0.78
56													0.77	0.85
% Variance	3.57	3.65	30.79	3.38	2.87	2.71	2.36	4.65	5.59	40.66	6.04	5.79	11.15	10.74
Eigenvalue	1.89	1.94	16.32	1.79	1.52	1.43	1.25	2.46	2.96	21.55	3.20	3.07	5.91	5.69

Principal axis factor analysis with varimax rotation and Kaiser normalisation

Factor loadings less than 0.40 have been omitted.

N= 284 Students in 10 classes

The percentage variance for the different WIHIC scales ranged from 2.36% to 30.79% for the pretest and from 2.71% to 40.66% for the posttest (see Table 4.1). The total proportion of variance accounted for by the seven WIHIC scales was 63.37% for the pretest and 71.58 % for the posttest. The eigenvalues ranged from 1.25 to 16.32 for the pretest and 1.43 to 21.55 for the posttest. A commonly-used criterion for the number of factors to rotate is the eigenvalues-greater-than-one rule, proposed by Kaiser (1960), that states that there are as many reliable factors as there are eigenvalues greater than one. Table 4.1 shows that all eigenvalues were greater than one.

The results of the factor analysis as shown in Table 4.1 strongly support the factorial validity of the final 53-item, seven-scale version of the WIHIC when used with my sample of students in Adelaide, South Australia.

4.2.2 Factor Structure of the Attitude and Efficacy Scales

To examine the internal structure of the 16 items of the attitude/efficacy scales, I conducted a similar principal axis factoring with varimax rotation and Kaiser normalization separately for pretest and posttest data for the sample of 284 students. Again, the criteria for the retention of any item were that it must have a factor loading of at least 0.40 on its *a priori* scale and less than 0.40 with every other scale in the same questionnaire. The application of these criteria led to the removal of one item (Item 14) from Academic Efficacy. After removal of this one item, the *a priori* scale structure of the attitude/efficacy questionnaire was replicated perfectly (see Table 4.2). The total proportion of variance for the attitude/efficacy scales was 70.82% for the pretest and 76.81% for the posttest. The eigenvalues ranged from 2.6 to 8.02 for the pretest and from 2.6 to 8.9 for the posttest and satisfy the greater-than-one rule proposed by Kaiser (1960).

The results in Table 4.2 of the factor analysis for the attitude and efficacy scales shows strong factorial validity for the final 15-item, two-scale version of the questionnaire when used with my sample of first-year high-school students in Adelaide, South Australia.

Table 4.2 Factor Analysis Results for the Attitude and Efficacy Scales for Pretest and Posttest

Item	Factor Loadings			
	Attitude to Subject		Academic Efficacy	
	Pretest	Posttest	Pretest	Posttest
1	0.91	0.92		
2	0.91	0.98		
3	0.91	0.95		
4	0.85	0.92		
5	0.77	0.86		
6	0.93	0.92		
7	0.70	0.72		
8	0.90	0.93		
9			0.89	0.86
10			0.86	0.91
11			0.79	0.83
12			0.91	0.85
13			0.91	0.89
15			0.73	0.83
16			0.44	0.69
% Variance	53.49	59.34	17.33	17.47
Eigenvalue	8.02	8.90	2.60	2.60

Principal axis factor analysis with varimax rotation and Kaiser normalisation

Factor loadings less than 0.40 have been omitted.

N= 284 Students in 10 classes

4.2.3 Internal Consistency Reliability

In order to examine the extent to which items in the same scale measure the same aspect, the reliability for each learning environment, attitude and efficacy scale was estimated for two units of analysis (the student and the class mean). The internal consistency reliability of each scale was calculated separately for pretest and posttest data using the Cronbach's alpha coefficient. Table 4.3 shows that, for the pretest, alpha coefficients for the nine scales ranged from 0.80 to 0.94 with the student as the unit of analysis and from 0.85 to 0.97 with the class as the unit of analysis and, for the posttest, alpha coefficients ranged from 0.87 to 0.95 with the student as the unit of analysis and from 0.83 to 0.92 with the class as the unit of analysis. An alpha coefficient of 0.7 is deemed as satisfactory and a value of 0.8 deemed as good (Cohen, 1988).

Table 4.3 Internal Consistency Reliability (Cronbach Alpha Coefficient) for Two Units of Analysis for the Modified WIHIC and Attitude/Efficacy Scales for Pretest and Posttest

Scale	Unit of Analysis	No of Items	Alpha Reliability	
			Pretest	Posttest
Learning Environment				
Student Cohesiveness	Individual	7	0.80	0.87
	Class Mean		0.90	0.91
Teacher Support	Individual	8	0.94	0.95
	Class Mean		0.97	0.92
Involvement	Individual	6	0.87	0.91
	Class Mean		0.92	0.83
Investigation	Individual	8	0.90	0.95
	Class Mean		0.94	0.92
Task Orientation	Individual	8	0.87	0.92
	Class Mean		0.85	0.90
Cooperation	Individual	8	0.89	0.93
	Class Mean		0.88	0.91
Equity	Individual	8	0.94	0.97
	Class Mean		0.94	0.97
Attitude/Efficacy				
Attitude to Subject	Individual	8	0.95	0.97
	Class Mean		0.98	0.98
Academic Efficacy	Individual	7	0.91	0.93
	Class Mean		0.90	0.90

N= 284 students in 10 classes

4.2.4 Discriminant Validity of WIHIC

A realistic representation of how factors are interrelated can be demonstrated through the oblique rotation in exploratory factor analysis (Brown, 2006; Field, 2009). Field (2009) argues that there should be a moderately strong relationship between factors. If the correlation between the factors is above 0.8, then this could suggest an interaction with similar concepts and therefore lead to poor discriminant validity (Brown, 2006). The results in Table 4.4 show the components correlation matrix, generated by using an oblique rotation for both the pretest and the posttest data and suggest that the WIHIC measured distinct constructs for both the pretest and the posttest in my study. The relatively low correlations in Table 4.4 suggest relatively little overlap of one WIHIC

scale with the other scales and compare favourably with discriminant validity data in studies involving the WIHIC (Dorman, 2003, 2008; Fraser, Aldridge & Adolphe, 2010; Ogbuehi & Fraser, 2007). The WIHIC has been shown to be valid and reliable in many studies across the world as reviewed in Section 2.2.3.

Table 4.4 Inter-correlations between WIHIC Scales for Pretest (Above the Diagonal) and Posttest (Below the Diagonal)

Scale	Correlations						
	Student Cohesiveness	Teacher Support	Involvement	Investigation	Task Orientation	Cooperation	Equity
Student Cohesiveness	-	0.55	0.17	0.19	0.15	0.20	0.24
Teacher Support	0.38	-	0.23	0.27	0.06	0.13	0.22
Involvement	0.41	0.24	-	0.26	0.36	0.22	0.32
Investigation	0.49	0.40	0.41	-	0.17	0.15	0.30
Task Orientation	0.26	0.19	0.41	0.26	-	0.19	0.16
Cooperation	0.26	0.52	0.20	0.25	0.11	-	0.36
Equity	0.53	0.29	0.37	0.31	0.30	0.28	-

N = 284 Students in 10 classes

4.2.5 Ability of the WIHIC to Differentiate between Classrooms

When an analysis of variance (ANOVA) was conducted for each learning environment scale for the pretest and posttest with class membership as the independent variable, it was found that nearly every WIHIC scale could differentiate significantly between the perceptions of students in different classrooms. The ANOVA results reported in Table 4.5 indicate that, apart from Involvement for the posttest and Cooperation for the pretest and posttest, all remaining scales differentiated significantly ($p < 0.05$) between classes for both the pretest and posttest. The η^2 values, which represent the degree of association between class membership and the dependent variable, ranged from 0.12 to 0.33 for the pretest and from 0.12 to 0.37 for the posttest. The WIHIC's factor structure, internal consistency reliability, discriminant validity and ability to differentiate between classrooms in my study were satisfactory and consistent with previous studies that were reviewed in Section 2.2.3 and which used the WIHIC across the world in Australia, Taiwan, Canada, Indonesia, Singapore and India (Aldridge,

Fraser & Huang, 1999; Aldridge & Fraser, 2000; Fraser, Aldridge & Aldolphe, 2010; Khoo & Fraser, 2008; Koul & Fisher, 2005; Zandvliet & Fraser, 2004, 2005).

Table 4.5 Ability of the WIHIC to Differentiate Between Classrooms (ANOVA Results) for Pretest and Posttest

Scale	Eta ²	
	Pretest	Posttest
Student Cohesiveness	0.12*	0.16**
Teacher Support	0.33**	0.37**
Involvement	0.15**	0.07
Investigation	0.12*	0.12*
Task Orientation	0.14**	0.12*
Cooperation	0.07	0.08
Equity	0.32**	0.24*

N= 284 students in 10 classes

* $p < 0.05$ ** $p < 0.01$

4.3 Differences between Instructional Methods and whether Instructional-Method Differences are Different for Males and Females

The second research question focused on a comparison of the project-based group with the non-project-based group in terms of learning environment, attitude, efficacy and achievement. The third research question involved whether any differences existing between instructional methods were similar or different for male and female students. Both of these research questions were investigated simultaneously by conducting a two-way MANOVA with my whole sample of 284 students for the seven WIHIC learning environment scales, two attitude/efficacy scales and one achievement scale as the set of 10 dependent variables.

Instructional method and student sex were the two independent variables. The presence or absence of a statistically-significant interaction between instructional method and sex was used to identify whether instructional-method differences were different or similar for males and females. Initially conducting MANOVA for the entire set of 10 dependent variables reduced the Type I error rate associated with conducting separate univariate tests for individual dependent variables. Using Wilks' lamda criterion, MANOVA revealed statistically significant results for instructional method ($F = 2.46$, $p < 0.01$), sex ($F = 2.16$, $p < 0.05$) and the instruction-by-sex interaction ($F = 2.10$, $p < 0.05$). Therefore, I was justified in interpreting the two-way ANOVA results separately for each of the 10 dependent variables.

4.3.1 Instructional-Method and Sex Difference for each WIHIC, Attitude/Efficacy and Achievement Scale

Table 4.6 provides the ANOVA results for instructional method, sex and the instruction-by-sex interaction separately for each learning environment and attitude scale. The F value is provided for each dependent variable, in addition to the η^2 statistic (which represents the proportion of variance accounted for). Table 4.6 shows that statistically significant results emerged for: instructional method for one learning environment scale (Equity) and Achievement; and sex for one learning environment scale (Cooperation) and Attitude to Subject. The instruction-by-sex interaction was statistically significant for one learning environment scale (Teacher Support) and for both attitude/efficacy scales of (Attitude to Subject and Academic Efficacy).

Table 4.6 Two-Way MANOVA/ANOVA Results (F and η^2) for Instructional-Method and Sex Difference for Each WIHIC, Attitude/Efficacy and Achievement Scale

Scale	Instruction Type		Sex		Instructional Method x Sex	
	F	η^2	F	η^2	F	η^2
Learning Environment						
Student Cohesiveness	0.11	0.00	3.51	0.01	0.99	0.00
Teacher Support	1.04	0.01	0.93	0.00	7.66**	0.03
Involvement	0.03	0.00	0.00	0.00	2.80	0.01
Investigation	0.88	0.00	1.12	0.01	2.10	0.01
Task Orientation	0.18	0.00	3.63	0.01	0.61	0.00
Cooperation	0.06	0.00	11.58**	0.04	2.41	0.01
Equity	4.60*	0.02	1.27	0.01	3.71	0.06
Attitude/Efficacy						
Attitude to Subject	0.07	0.00	5.82*	0.02	12.36**	0.04
Academic Efficacy	0.13	0.00	0.34	0.00	6.71**	0.02
Achievement	11.15**	0.04	0.01	0.00	0.32	0.00

$N=91$ males and 101 females in classes that were project-based and 47 males and 45 females in classes that were not project-based.

* $p<0.05$ ** $p<0.01$

4.3.2 Instructional-Method Differences in Learning Environment, Attitude and Achievement Scales

Table 4.7 provides for each learning environment, attitude and achievement scale the average item mean, the average item standard deviation, and the ANOVA results repeated from Table 4.6. The average item mean is simply the scale mean divided by the number of items in a scale. It is useful for comparing the means of scales containing different numbers of items. Percentage achievement scores were divided by 10 to provide a score range similar to other scales. As well, Table 4.7 provides an effect size for the instructional-methods difference for each scale. Cohen's d is the difference between the means for the two instructional methods divided by the pooled standard deviation for each learning environment, attitude/efficacy and achievement scale. The effect size conveniently expresses a difference between two groups in standard deviation units. According to Cohen (1988), effect sizes range from small (0.2) to medium (0.5) to large (0.8).

Table 4.7 shows that, for the 10 scales, mean scores were somewhat less favourable for the project group for five of the seven learning environment scales, more favourable for the project group for both attitude/efficacy scales and less favourable for the project group for achievement. However, for most scales, these differences between project and non-project students were both small and statistically nonsignificant. Relative to non-project students, project students perceived a significantly less positive classroom environment for Equity and had significantly lower achievement scores. For these two scales, effect sizes were 0.26 and 0.44 standard deviations, respectively, which are in the small range according to Cohen's (1988) criteria with perhaps the exception of Achievement (modest effect size of 0.44 standard deviations). However, because of the existence of significant instruction-by-sex interactions for three scales (Table 4.6), instructional-method differences for these three scales (Teacher Support, Attitude to Subject and Academic Efficacy) are revisited in Section 4.3.3.

Table 4.7 Average Item Mean, Average Item Standard Deviation and Difference between Instructional Methods (Cohen's *d* Effect Size and ANOVA Results) for Each Learning Environment, Attitude/Efficacy and Achievement Scale

Scale	Item Mean		Item SD		Difference	
	Project	Non-Project	Project	Non-Project	<i>d</i>	<i>F</i>
<i>Learning Environment</i>						
Student Cohesiveness	4.08	4.10	0.67	0.63	-0.03	0.11
Teacher Support	3.60	3.70	0.95	0.81	-0.11	1.04
Involvement	3.27	3.28	0.79	0.86	-0.01	0.03
Investigation	3.39	3.48	0.79	0.90	-0.11	0.88
Task Orientation	4.10	4.01	0.71	0.80	0.12	0.18
Cooperation	3.97	3.97	0.77	0.86	0.00	0.06
Equity	3.75	3.99	0.97	0.87	-0.26	4.60*
<i>Attitude/Efficacy</i>						
Attitude to Subject	3.05	3.00	1.06	1.07	0.05	0.07
Academic Efficacy	3.19	3.14	0.87	0.85	0.06	0.13
<i>Achievement</i>	5.99	6.41	0.96	0.97	-0.44	11.15**

N=192 project and 92 non-project students

p*<0.05 *p*<0.01

Effect size was calculated using the following formula: $d = (M_1 - M_2) / \sqrt{[(\sigma_1^2 + \sigma_2^2) / 2]}$

4.3.3 Sex Differences in Learning Environment, Attitude and Achievement Scales

Table 4.8 provides ANOVA results (repeated from Table 4.6) and effect sizes for sex differences in the 10-learning environment, attitude/efficacy and achievement scales. These sex differences were statistically significant for one learning environment scale (Cooperation) and for Attitude to Subject. For these two scales with significant sex differences, effect sizes were 0.37 and 0.15 standard deviations, respectively, which would be classified as small according to Cohen's (1988) criteria. Interestingly, for the two scales for which sex differences were statistically significant, females held somewhat more favourable perceptions and attitudes than males. However, because of the existence of a significant instruction-by-sex interaction for three scales (see Table 4.6), sex differences need to be reconsidered for those scales (see Section 4.3.4).

Table 4.8 Average Item Mean, Average Item Standard Deviation and Sex Difference (Cohen's *d* Effect Size and ANOVA Results) for Each Learning Environment, Attitude/Efficacy and Achievement Scale

Scale	Item Mean		Item SD		Difference	
	Male	Female	Male	Female	<i>d</i>	<i>F</i>
<i>Learning Environment</i>						
Student Cohesiveness	4.02	4.15	0.65	0.65	-0.20	3.51
Teacher Support	3.63	3.63	0.87	0.95	0.00	0.93
Involvement	3.30	3.24	0.80	0.82	0.07	0.00
Investigation	3.39	3.45	0.84	0.82	-0.07	1.12
Task Orientation	4.00	4.16	0.75	0.73	-0.22	3.63
Cooperation	3.82	4.11	0.79	0.78	-0.37	11.58**
Equity	3.81	3.85	0.90	0.98	-0.04	1.27
<i>Attitude/Efficacy</i>						
Attitude to Subject	2.95	3.11	1.10	1.01	-0.15	5.82*
Academic Efficacy	3.19	3.16	0.89	0.85	0.03	0.34
<i>Achievement</i>						
	6.13	6.12	1.09	0.96	0.01	0.01

N=138 males and 146 females

p*<0.05 *p*<0.01

Effect size was calculated using the following formula: $d = (M_1 - M_2) / \sqrt{[(\sigma_1^2 + \sigma_2^2) / 2]}$

4.3.4 Interaction between Instructional Method and Sex

Table 4.6 shows that the instruction-by-sex interaction was statistically significant for one learning environment scale (Teacher Support) and for both Attitude to Subject and Academic Efficacy. This suggests that the above interpretation of results separately for instructional method (Table 4.7) and sex (Table 4.8) are not valid and meaningful and need to be modified in the case of these three scales.

Table 4.9 provides the mean and standard deviation for each scale for four subsamples: project-based males, project-based females, non-project-based males and non-project-based females. Also, for each scale, the effect size (number of standard deviations) is shown for sex differences in scores separately for the project and non-project groups.

Table 4.9 Average Item Mean, Average Item Standard Deviation and Sex Difference (Effect Size) for Two Instructional Methods for Learning Environment, Attitude/Efficacy and Achievement Scales

Scale	Instructional Method	Average Item Mean		Average Item Standard Deviation		Male–Female Difference
		Male	Female	Male	Female	Effect Size <i>d</i>
<i>Learning Environment</i>						
Student Cohesiveness	Project-Based	4.01	3.99	0.67	0.62	0.03
	Not Project-Based	4.12	4.23	0.66	0.62	-0.17
Teacher Support	Project-Based	3.70	3.51	0.89	0.82	0.22
	Not Project-Based	3.50	3.93	0.99	0.75	-0.49
Involvement	Project-Based	3.36	3.20	0.80	0.80	0.20
	Not Project-Based	3.19	3.38	0.77	0.93	-0.22
Investigation	Project-Based	3.41	3.36	0.82	0.77	0.06
	Not Project-Based	3.38	3.63	0.77	0.91	-0.30
Task Orientation	Project-Based	4.04	3.93	0.71	0.81	0.14
	Not Project-Based	4.15	4.18	0.71	0.77	-0.04
Cooperation	Project-Based	3.88	3.75	0.75	0.85	0.16
	Not Project-Based	4.01	4.24	0.77	0.80	-0.29
Equity	Project-Based	3.80	3.83	0.89	0.94	-0.03
	Not Project-Based	3.71	4.19	1.03	0.75	-0.53
<i>Attitude/Efficacy</i>						
Attitude to Subject	Project-Based	3.13	2.63	1.07	1.10	0.46
	Not Project-Based	2.98	3.41	1.04	0.87	-0.45
Academic Efficacy	Project-Based	3.30	2.98	0.85	0.92	0.36
	Not Project-Based	3.01	3.33	0.88	0.74	-0.39
<i>Achievement</i>						
	Project-Based	5.96	6.44	0.98	1.01	-0.48
	Not Project-Based	6.02	6.36	0.96	0.95	-0.36

N=284 (91 males and 101 females in classes that were project based and 47 males and 45 females in classes that were not project based)

p*<0.05 *p*<0.01

Effect size was calculated using the following formula: $d = (M_1 - M_2) / \sqrt{[(\sigma_1^2 + \sigma_2^2) / 2]}$

The last column of Table 4.9 shows an interesting pattern in the sign/direction of sex differences for the project group relative to the non-project group. For most scales, males scored somewhat more highly than females in the project group, but females scored somewhat more highly than males in the non-project group. Although these differences typically were small in magnitude and the instruction-by-sex interaction

was statistically nonsignificant for most scales, still the pattern of results in Table 4.9 suggests that the project method was differentially effective for males and females, with males benefitting more from the project approach and females benefiting more from traditional (non-project) methods. In order to interpret the statistically significant instruction-by-sex interactions for Teacher Support, Attitude to Subject and Academic Efficacy, graphs are shown in Figure 4.1.

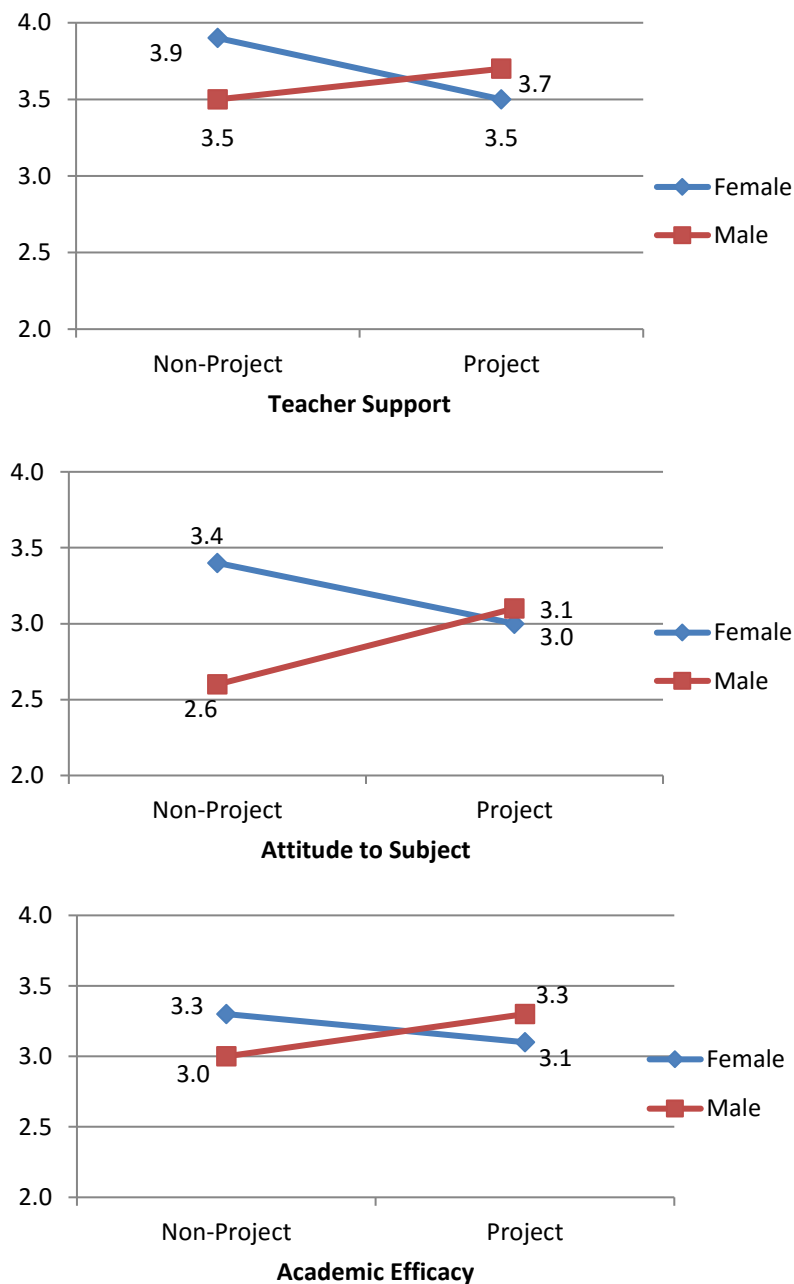


Figure 4.1: Statistically-Significant Interactions between Instructional Method and Sex

The interpretation of all three significant interactions is similar: the project method was differentially effective for male and female students, with males benefitting more from the project method and females benefitting more from the traditional/non-project methods.

By simultaneously considering Table 4.6 and Figure 4.1, the following refined interpretations emerge from the three scales (Teacher Support, Attitude to Subject and Academic Efficacy) for which a significant instruction–by–sex interaction was found:

- Although overall Teacher Support scores were not significantly different either for different instructional methods or for different sexes, males benefitted more from the project approach whereas females benefitted more from traditional methods.
- Overall, for Attitude to Subject, scores were not significantly different for different instructional methods, but females scored significantly more highly than males. Nevertheless, females enjoyed mathematics more under the traditional non-project method, whereas males' Attitude to Subject was similar under either instructional method.
- Although overall Academic Efficacy scores were not significantly different either for different instructional methods or for different sexes, males benefitted more from the project approach whereas females benefitted more from traditional methods.

4.4 Associations between Learning Environment, Attitude to Subject, Academic Efficacy and Achievement

The fourth research question focused on associations between the dimensions of the learning environment and the student outcomes of attitudes, academic efficacy and achievement. Therefore associations between three student outcomes (Attitude to Subject, Academic Efficacy and Achievement) and the 7 classroom learning environment scales of the WIHIC were examined for my sample of 284 students. A simple correlation analysis was used for examining the bivariate association between each learning environment scale and each student outcome. A multiple regression analysis was used for each outcome to provide information about the multivariate

association between each student outcome and the set of 7 learning environment scales. The regression coefficients were used to identify which learning environment scales contributed most to variance in student outcomes when all other learning environment scales were mutually controlled.

Table 4.10 reports the results of the analyses using simple correlation and multiple regression for associations between the seven learning environment scales and the student outcomes of Attitude to Subject, Academic Efficacy and Achievement. This table provides the simple correlation (r) between each of the seven learning environment scales and each of the student outcomes, the multiple correlation R between the set of seven learning environment scales and each outcome, and the standardised regression coefficient (β) for each of the learning environment scales for each of the three student outcomes.

4.4.1 Environment-attitude associations

Table 4.10 shows that, with the individual student as the unit of analysis, all seven learning environment scales of the WIHIC were correlated positively and significantly ($p<0.01$) with Attitude to Subject. The simple correlation analysis suggests a bivariate association between Attitude to Subject and a greater emphasis on all of the learning environment scales.

The multiple correlation (R) reported in Table 4.10 between the 7 learning environment scales and the Attitude to Subject scale at the individual student level of analysis was 0.63 and was statistically significant ($p<0.01$). In considering the standardised regression weights to provide information about which of the seven learning environment scales of the WIHIC uniquely contributed to the variance in the Attitude to Subject scale when the other learning environment scales are mutually controlled, Table 4.10 shows that three WIHIC scales (Teacher Support, Investigation and Task Orientation) were statistically significant ($p<0.05$).

4.4.2 *Environment-efficacy associations*

The results of the simple correlation analysis as reported in Table 4.10 show that all seven learning environment scales of the WIHIC were correlated positively and significantly ($p<0.01$) with the Academic Efficacy scale. The multiple correlation (R) reported on the bottom of Table 4.10 between the 7 learning environment scales and the Academic Efficacy scale at the individual student level of analysis was 0.65 and was statistically significant ($p<0.01$). As for Section 4.4.1, when the standardised regression weights were used to provide information about which of the seven learning environment scales of the WIHIC contributed uniquely to the variance in the Academic Efficacy scale when the other learning environment scales were mutually controlled, Table 4.10 shows that three WIHIC scales (Involvement, Investigation and Task Orientation) were statistically significant ($p<0.01$).

4.4.3 *Environment-achievement associations*

My study also considered whether associations existed between dimensions of the learning environment and achievement, which was measured through a simple mathematics test of academic competency. The results of the simple correlation analysis reported in Table 4.10 show that four of the learning environment scales (Involvement, Investigation, Task Orientation and Equity) of the WIHIC were correlated positively and significantly ($p<0.01$) with Achievement. The multiple correlation (R) reported in Table 4.10 between the 7 learning environment scales and Achievement was 0.30 and was statistically significant ($p<0.01$). In examining the standard regression weights, one WIHIC scale (Task Orientation) was a statistically-significant ($p<0.05$) independent predictor of achievement.

All statistically significant relationships were positive for both the simple correlation and multiple regression analysis, suggesting a positive association between Attitude to Subject, Academic Efficacy, Achievement and the dimensions of learning environment. My results for outcome–environment associations replicate and are consistent with past learning environment research involving the use of the WIHIC as reviewed in Fraser (2012) and Section 2.2.5. Research into associations between

learning environment and student outcomes has become one of the strongest traditions with studies dating back over 30 years (Fisher, Henderson & Fraser, 1997; Goh, Young & Fraser, 1993; Fraser & McRobbie 1995; McRobbie & Fraser, 1993; Wong & Fraser, 1996). More recent studies which investigated student cognitive and affective learning outcomes with student perceptions of the classroom learning environment using the WIHIC include: Afari, Aldridge, Fraser and Khine (2015), Chionh and Fraser (2009), Cohn and Fraser (2016), Fraser, Aldridge and Aldolphe (2010), Martin-Dunlop (2016) and Rita and Martin-Dunlop (2011).

Table 4.10 Simple Correlation and Multiple Regression Analyses for Associations between Three Student, Outcomes (Attitude to Subject, Academic Efficacy and Achievement and Scales of the WIHIC

Scale	Learning Environment–Outcome Associations					
	Attitude to Subject		Academic Efficacy		Achievement	
	<i>r</i>	β	<i>r</i>	β	<i>r</i>	β
Student Cohesiveness	0.30**	-0.05	0.35**	-0.06	0.06	-0.10
Teacher Support	0.53**	0.23**	0.32**	-0.06	0.11	-0.12
Involvement	0.44**	0.09	0.56**	0.32**	0.20**	0.15
Investigation	0.50**	0.14*	0.56**	0.21**	0.23**	0.11
Task Orientation	0.52**	0.22**	0.53**	0.27**	0.23**	0.20*
Cooperation	0.37**	0.00	0.46**	0.09	0.09	-0.11
Equity	0.51**	0.14	0.31**	-0.04	0.17**	0.11
Multiple Correlation (<i>R</i>)	0.63**		0.65**		0.30**	

* $p < 0.05$ ** $p < 0.01$

N = 284 Students in 10 classes

4.5 Using Qualitative Data to Explain Survey Findings

Combining quantitative and qualitative data in learning environment research is desirable as it can provide a better understanding of the research problem and questions. Capitalising on the strengths of each method, while compensating for each method's weaknesses, provides for a more credible outcome when comparing different classroom learning environments (Fraser & Tobin, 1991; Tobin & Fraser, 1998). Previously in Section 3.4, it was established that the primary data-collection method for this study was the administration of a questionnaire involving scales from the WIHIC, with scales from the TOSRA and MJSES that assess students' perceptions of their learning environment, attitudes and academic efficacy.

Because my study involved the effectiveness of project-based mathematics, providing qualitative data could illuminate possible trends and explanations for the quantitative results. As recommended by Tobin and Fraser (1998), this study involved an explanatory mixed-method design and used a two-phase approach (Creswell & Plano Clark, 2007). The first phase involved the collection of quantitative data, followed by a second phase of collecting qualitative data to help to explain and elaborate the quantitative results. This provided a general picture of the research problem as well as further analysis using qualitative methods to refine the quantitative results (Creswell, 2008).

My study involved a minor qualitative data-collection component involving observations and interviews in order to gain a deeper insight into the key quantitative findings. Whilst this component was relatively small, it was useful in providing qualitative data related to these key findings. Analyses of the quantitative data showed that, for most scales, males scored somewhat higher than females in the project groups, whilst females scored somewhat higher than males in the non-project group. These differences were small in magnitude, but a pattern emerged which suggested that the project method was differentially effective for males and females. The statistically-significant instruction-by-sex interaction for Teacher Support, Attitude to Subject and Academic Efficacy led to a more refined interpretation for these three scales. Therefore, the analyses of the qualitative data were narrowed to focus on the

differential effectiveness of instructional methods for males and females.

The classroom setting for project-based learning is very different from traditional classrooms because, in project-based learning, a large proportion of the work is completed in small groups and requires collaboration between students (Baron, 2011; Grant, 2010). Project-based learning is focussed on student-centred learning, whilst traditional classrooms tend to be more teacher-directed. The traditional classrooms, at the high school in which the study took place, were highly regulated, with teachers following formal structures, rules and procedures, particularly in terms of student management and teaching methodology. Students were seated in standard rows with desks. Class rules, which include students asking for teacher support, teacher control of student collaboration, the level of noise and individual task orientation, were strictly enforced and were common in traditional classrooms.

This regular routine was changed to accommodate a new strategy of project-based learning, which became the core of each mathematics topic. The curriculum was modified to include these activities which complemented the core mathematical concepts from each topic. The classroom was changed with tables re-arranged to accommodate group work to become more dynamic, students were engaged in their own self-directed group projects, and it was noticeably noisier. Groups were established using student-choice based on friendship and, in most classes, with most self-selected groupings being single sex. Students had access to a broad range of resources and equipment and a greater emphasis on digital learning and online collaboration in project-based learning.

Qualitative data analysis involved categorising data from interviews and observations, using each of the scales from the questionnaire. Qualitative data analysis led to the emergence of three themes that are discussed in Sections 4.5.1 to 4.5.3:

- Pedagogy of project-based learning and the role of the teacher
- Sex-related differences in project-based learning
- Attitude and academic efficacy in project-based learning

4.5.1 Theme 1: Pedagogy of Project-based Learning and the Role of the Teacher

The quantitative results included a statistically significant instruction-by-sex interaction for one learning environment scale, Teacher Support. Table 4.9 and Figure 4.1 show an interesting pattern in which there was a slightly higher Teacher Support mean for male students in project-based classes (3.7) compared with males in traditional classes (3.5), whilst there was a slightly lower mean for females in project-based classes (3.5) compared to females in traditional classes (3.9).

Although Teacher Support was relatively consistent in all classes, qualitative data revealed higher levels of frustration and anxiety when an innovation was introduced, which could lead to student perceptions of lower Teacher Support. Perhaps this is highlighted in Figure 4.1 which shows a more perceived Teacher Support in traditional classes over project-based classes for female students and the opposite for male students.

The pedagogy used by teachers in project-based classes was different from that in a traditional class setting and, for students to be successful in project-based learning, teachers adopted new classroom strategies. Analysis of the qualitative data suggests that students in project-based classes tended to be more reliant on their teacher than in traditional non-project-based classes. The qualitative data revealed that some students found project-based activities confusing and had difficulty making immediate progress with their task, which resulted in various degrees of frustration and anxiety.

Teacher Support is described as the extent to which a teacher develops a positive relationship with students in the class, interacts, helps, supports and shows an interest in students' learning (Aldridge & Fraser, 2008). The degree of Teacher Support could be perceived by students in terms of the relationship between the teacher and students and the impact of the teacher in supporting students in their learning.

There were subtle differences in the way in which teachers interacted with students in this study. In non-project-based classes, teachers typically used direct instruction, which generally took an approach of Explain, Demonstrate and Practice (EDP). In direct instruction, students were introduced to new concepts with a teacher connecting

previous knowledge with new content and relevance (Explain). This was followed by a demonstration involving applying concepts through a range of examples (Demonstrate), before students applied their knowledge and understanding by practising problems (Practice).

In project-based classes, teachers used a different approach which followed a strategy of Explain, Collaborate, Develop, and Review (ECDR). The Explain phase included an outline of the project, its objectives, the process and guidelines and resources available. The Collaborate phase included teachers scaffolding the process into smaller tasks for groups to engage in a range of collaborative activities which included group selection, group rules and guidelines, brainstorming ideas, creating concepts and establishing resource requirements. In the Develop phase, students proceeded with the task of establishing their research (problem) question and developing their project through to outcomes or solutions. The Review phase included a self and group review of students' experience and was part of the assessment of the project-based task. In project-based learning, students were required to use their own initiative, with a large emphasis on being independent, self-reliant and collaborative.

It became evident during observations that students heavily depended on teacher support during the initial stages of the project. Many questions were asked after the teachers introduced the topic and as they were busily circulating in their classrooms attending to different groups. This was common for all project-based classes in the initial phase of the project, with one female teacher stating that "it was a real challenge to support all groups meaningfully...so many different projects" and one male teacher describing that "I was swamped with questions even after I had explained the task and requirements explicitly". One teacher reported:

Sometimes I find that, when you start talking about PBL, the students can be a little bit hesitant, because it's new, it's unknown territory, and particularly with this class because students are so used to having very structured lessons. They were a bit hesitant because they had to control what they were doing, work as a group and rely on each other.

And another teacher stated:

At first I think it required a bit of structure from myself, mainly just because the students weren't used to this style of learning, because I didn't do enough of it in the classroom. So when I gave them the opportunity to now put the question back to them and for the students to start coming up with their own questions, at first they were hesitant, and they would keep asking for clarification from me. But as the time went on and they got more confident in themselves and in the project, I found that they took greater control of the task, and I didn't have to be involved as much as I did at the beginning of the activity.

During observations, there was a noticeable level of uncertainty and anxiety on the part of many students, there was a lot of discussion and some students became concerned with what was actually achieved in the lesson in terms of written work. Perhaps this was because students had to work in a group setting and did not know their role. One female student stated that "we got into our groups and we all looked at each other wondering what to do next". Female students reported that they were unsure of what was expected of them. One female student reported that "I was so stressed and I could not ask my team mates...I did not know where to start". On the other hand, a male student reported that "this was a great activity and we got onto our computer and brain-stormed our ideas". Teachers who had scaffolded the project into small tasks with detailed explanations were more successful in assisting students in their task. Students in both project and non-project classes held their teachers in high regard: one female student stated that: "Ms R always helps me to understand my maths problem and sometimes she tells me to stay a few minutes after school"; a male student said that: "Mr M is awesome, he is very patient with us even when we muck around"; and another male student said that: "my teacher is always happy to help and answer my questions at any time even using email".

The reason why female students in project-based classes were more reliant on their teacher could be found in the observations from their teachers, who reported that female students have higher academic expectations and spend an extraordinary amount of time on their task to get it perfect.

It was most evident that students heavily depended on teacher support during the initial stages of my study. However, it was noted that the level of teacher support did not diminish over time; indeed students' continued to display behaviours requiring a high level of teacher support in PBL classes.

Whilst the findings in Section 4.3.4 did not include a significant difference between project-based and non-project-based classes in Teacher Support, the qualitative data did provide a richer explanation in terms of the difference in pedagogy and role of the teacher when comparing project-based classes and traditional classes. The explanation could well sit with the challenge facing teachers in modifying their own teaching practice to accommodate a new strategy and, at the same time, experiencing a high demand on their time to support different groups in their class. Qualitative data showed that female students were much more reliant on teacher support than male students.

It appears that the three overarching factors which could influence students' perception of Teacher Support include the readiness for a teacher to adapt to a new role in supporting students through project-based learning, the particular needs of all students in a class when introduced to a new innovation in mathematics, and students' readiness to transition from a traditional into project-based learning environment.

4.5.2 Theme 2: Sex-related Differences in Project-based Learning

The quantitative data in Section 4.3.3 indicated that, for most scales, males scored somewhat more highly than females in the project-based group, but females scored somewhat more highly than males in the non-project-based group. Although differences were typically small in magnitude and the instruction-by-sex interaction was statistically nonsignificant for most scales, a pattern was evident which suggested that the project method was differentially effective for males and females, with males benefitting more from the project approach and females benefitting more from traditional (non-project-based) method.

This result was surprising because initial observations suggested the opposite, with females showing greater aptitude and focus on a project-based task, whilst males showed enthusiasm but were more haphazard in their approach to project-based tasks. Consequently, this theme required deeper investigation into why females preferred a traditional approach over a project-based approach. The assertion is that females and males place a different value on the importance of project-based activity on the basis of their academic aspirations. In other words, females see benefit in this approach if it builds on their progress in mathematics, whilst males place more value on the process in the project-based approach.

An analysis of the qualitative data suggests that the project-based learning experience was positive for both groups because they enjoyed a new approach more than the traditional form. However, females took longer to get started on the project-task because they used time to deliberate, plan and consider their ideas, whilst males tended to launch into the task, often without a plan. As one teacher stated:

Girls are more organised. I would say girls are more thorough in the way that they show their planning when they do their mathematics, so they set out their working; they're more particular about that. Their presentation of their work is generally at a higher standard than for boys. Girls seem to take a little bit more interest, or they feel it's more important that they show me the entire process. Boys I would think - and this is pretty general - tend to - once they know the answer, they'll give you the answer, and they're not as interested in having to show you the process. A boy will say, well I've done the answer, I know what I'm doing, why do I need to explain it to you?

Females were observed to work well within their groups and they were on task, but they did rely heavily on their teacher for support as one teacher stated:

I find that girls can be really less confident, and I'm continually being called over to the girls' groups. Am I doing this right? Have I got the right answer? Is this perfect enough? Is this font okay? I'm really hesitant about showing you my work, because this isn't just a problem, this is you know my creativity, this is my maths, this is my thinking, this is my everything and I have to show you.

And another teacher observed:

I feel that girls are more motivated, and so whether or not that comes down to being because they talk about it more and bounce ideas off each other, and grow from there as opposed to the boys, who in my class were quieter - they probably didn't have that conversation where they were sort of talking the problem over with each other.

In the final stages of each project, it was obvious in most classes that the thoroughness by female students became evident in their final products. Quality of work, time management, presentation, organisation and articulation of learning goals were of a higher standard compared with the male students. As one teacher observed:

The way work was presented by the girls was of a higher quality than the boys. But the actual content of the work was very similar. But the way that the girls articulated it and presented it on their posters was of a high standard, the way it was presented, and how the girls had broken the information up - for someone looking at the posters, it was clear, succinct and you could understand it; it came across clearer.

Males enjoyed the freedom and the process. One male student said that "I really enjoyed working with my friends and having a say in how we can do the problem" and another male student commented that "I think we worked well as a group, we enjoyed working out the mathematics and solving the problem, we also liked to use our laptop computers". On the other hand, a female student commented on the project-based approach: "I think that we did learn from PBL, but we also learned a lot more from the textbook work because it has more questions and you cover a lot more, which is important for our final Maths grade". Another female student said: "I feel that I have gone backwards in my overall Maths grade from last year. I don't feel I have made as much progress because of PBL."

Project-based learning provides a range of challenges not the least being the deeply-held views of students about its relevance in relation to their learning. Whilst holistically project-based learning offers opportunities for students to develop a range of skills in addition to mathematical knowledge, such as inquiry, group work, communication, project methods, self-review and many more, in the context of mathematics, students have deeply-held views of what is expected of them and how

they engage with mathematics. This is well reported in past research in the area of gender and mathematics (Baker, 2002; Britner, 2008; Fennema & Sherman, 1978; Usher & Pajares, 2005). The work of Ma and Cartwright (2003) reported in Section 2.4 encompasses anxiety towards mathematics and the utility of mathematics. They found gender differences and alarmingly a decline in outcomes for males and females. More specifically, female anxiety grew faster than male anxiety towards mathematics and there were differences between males and females in terms of understanding mathematics as a process-oriented activity.

4.5.3 Theme 3: Attitude and Academic Efficacy in Project-based Learning

The third and final theme involved an explanation for the quantitative findings as reported in Section 4.4.1 for Attitude to Subject and Section 4.4.2 for Academic Efficacy. Analysis confirmed a positive association between the learning environment and Attitude to Subject and Academic Efficacy. All seven learning environment scales of the WIHIC were correlated positively and significantly ($p < 0.01$) with Attitude to Subject and Academic Efficacy. Past research has shown that key indicators of success in an effective project-based learning environment are student engagement, motivation, and involvement with essential skills, such as team work, collaboration, communication and research (Albanese & Mitchell, 1993; Coliver, 2000; Gijbels et al., 2005; Mergendollar, Maxwell & Belisimo, 2006).

Observations of lessons and interviews with teachers involved in project-based classes suggested that students who are involved in project-based learning in a positive learning environment experience more positive attitudes and higher levels of academic efficacy. As one teacher stated:

Boys can get less motivated with rote learning, whereas girls for some reason tend to really like rote learning, try to get through all the questions, and do their homework more often than the boys. There are exceptions to that of course. But boys, once they think they've got it, then switch off. If they're confident that they've got it, that's it for them, whereas project-based learning allows them to keep going and you can actually extend them and they find it more challenging, which they like once they've gotten used to the idea. They are a little bit hesitant at the start.

And another teacher explained:

I find boys are better at project-based learning and they take on the problem solving a bit better because, when they can start linking the problem solving to the real world applications, they go with it and they remember it. Whereas the girls have more or less stayed the same with their grades, except some who struggle with mathematics actually go backwards. It could be to do with their effort.

Yet another teacher elaborated:

For some students who are a little quieter, I find that they are more willing to try because, even if they are showing you something that is more research based in terms of gathering data, they are more willing to show you that they can do something and they are not so worried about whether they get it wrong. Girls are hesitant to try it first, and they often need to check on their progress. Their attitude to lessons can be better, they start looking forward to their lessons. But they still want you to have a lesson where I am expected to explain the maths behind this, so that they can go and do it. They take their extra notes, and they say right, this is for this question in PBL, or this is this part that I have got to work out. They are still very conscious that they want to know how to work it out like they are asked to do in textbook work.

Students reported positively about their mathematics experience and they enjoyed the change from traditional methods to a project-based method. As one male student said: “I was very happy with our project-based classes; it provided a change from textbook learning which gets very repetitious and boring.” Another male student said: “I found the project task of developing a new suburb really interesting; I enjoy using my computer to do research.” A female student however said that: “I enjoyed our projects but I could not see how this was relevant to what we had to know in mathematics. I am really worried about that.”

It was evident from observations and interviews that students enjoyed the experience of project-based learning and that the challenge of working in this context stretched students’ mathematical thinking skills. There were a range of challenges which included working successfully in groups, equity in terms of effort from all group members, distractions and focus, relevance and different ability groups; however, it

did not detract from the students' endeavour and commitment. Students reported positive attitudes to subject and high levels of academic efficacy, with learning preferences being evident and with females preferring a traditional approach and males preferring a project-based approach.

Insights from the qualitative data supported and embellished the quantitative findings and provided an explanation of why female students preferred traditional methods to project-based methods, whereas males preferred project-based methods to traditional methods. Whilst both males and females enjoyed the change from traditional methods to project-based methods, females were not convinced of the relevance and efficacy of a project-based approach to learning mathematics. Females generally found the approach somewhat confusing and became anxious about not being able to complete the tasks to a high standard. On the other hand, males typically enjoyed the project-based approach, were motivated and interested in the applied nature of the tasks, working in teams and working in a climate of autonomy. This could explain the quantitative results as described in Section 4.3 and in Figures 4.1, 4.2 and 4.3.

4.6 Concluding Remarks

This chapter has reported the analyses and findings for my four research questions, which included the factor structure, internal consistency reliability and discriminant validity of the WIHIC and modified Attitude/Efficacy scales, as well as the ability of the WIHIC to differentiate between classrooms when used with a sample of 284 first-year high-school students from a coeducational secondary school in Adelaide, South Australia. I also examined whether the project method was effective overall, as well as differentially effective for males and females, in terms of learning environment, attitude to subject, academic efficacy and achievement. Associations between student outcomes (attitude to subject, academic efficacy and achievement) and learning environment were also analysed.

The internal structure of the 56-items of the seven-scale WIHIC was examined using principal axis factor analysis with varimax rotation and Kaiser normalisation separately for pretest and posttest data. A similar factor analysis was used to examine the internal structure of the attitude scale (Attitude to Subject from the TOSRA) and

the efficacy scale (Morgan-Jinks Efficacy scale). All items from the WIHIC except three had factor loadings of at least 0.4 on their own scale and less than 0.4 on other scales, resulting in a version of the WIHIC comprising 53 items in seven scales. The total proportion of variance accounted for by the seven WIHIC scales was 63.37% for the pretest and 71.58% for the posttest. All items of the Attitude/Efficacy scales except one had factor loadings of at least 0.4 on their own scale and less than 0.4 on the other scale. The total proportion of variance for the attitude/efficacy scales was 70.82% for the pretest and 76.81% for the posttest.

The alpha coefficients for the nine learning environment and attitude scales for the pretest ranged from 0.80 to 0.94 with the student as the unit of analysis and from 0.85 to 0.97 with the class as the unit of analysis. For the posttest, the alpha coefficients ranged from 0.87 to 0.95 with the student as the unit of analysis and from 0.83 to 0.92 with the class as the unit of analysis. Discriminant validity analyses suggested that the separate scales from the WIHIC measured relatively distinct aspects of the classroom learning environment, attitudes and academic efficacy.

When an analysis of variance (ANOVA) was conducted for each learning environment scale for the pretest and posttest data with class membership as the independent variable, it was found that nearly every WIHIC scale could differentiate significantly between the perceptions of students in different classrooms. The η^2 values, which represent the degree of association between class membership and the dependent variable, ranged from 0.12 to 0.33 for the pretest and from 0.12 to 0.37 for the posttest. My findings for the validity and reliability of questionnaires are consistent with previous studies that have used the WIHIC (Aldridge & Fraser, 2000; Ogbuehi & Fraser, 2007; Dorman, 2008; Rita & Martin-Dunlop, 2011).

A comparison of the project-based group with the non-project-based group in terms of learning environment, attitude, efficacy and achievement scales, together with an analysis of whether any differences existing between instructional methods were similar or different for male and female students, were the basis of Research Questions 2 and 3. Both of these research questions were investigated simultaneously by conducting a two-way MANOVA involving the WIHIC learning environment scales,

two attitude/efficacy scales and one achievement scale as the set of 10 dependent variables. Instructional method and student sex were the two independent variables. ANOVAs for instructional method and sex for each learning environment and attitude scale revealed some statistically-significant differences. However, because of the existence of significant instruction-by-sex interactions for three scales (Teacher Support, Attitude to Subject and Academic Efficacy), instructional method differences were revisited.

The re-examination of the average item mean and male–female difference for each of the scales for project-based classes/non-project-based classes, indicated a pattern in the sign/direction of sex differences for the project group relative to the non-project group emerged. For most scales, males scored somewhat more highly than females in the project group, but females scored somewhat more highly than males in the non-project group. Although these differences typically were small in magnitude and the instruction-by-sex interaction was significant only for three dependent variables, still the pattern suggests that the project method was differentially effective for males and females, with males benefitting more from the project approach and females benefitting more from traditional (non-project) methods.

The use of simple correlation and multiple regression analyses revealed relationships between students' perceptions of the learning environment and the student outcomes of attitude to subject, academic efficacy and achievement. All seven learning environment scales of the WIHIC were correlated positively and significantly with Attitude to Subject and Academic Efficacy and four learning environment scales were significantly correlated with achievement. The statistically-significant multivariate relationships revealed through the multiple correlation analysis showed that associations between the learning environment and students' Attitude to Subject, Academic Efficacy and Achievement were positive and consistent with previous studies in learning environment research (Fraser, 2012, 2014).

Qualitative data gathered from observations in three project-based classes, coupled with interviews involving 28 students and 3 teachers, were used to explain quantitative findings through an analysis of themes. Qualitative data generally supported and

embellished the quantitative findings concerning the differential effectiveness of project-based mathematics for males and females with females preferring traditional methods over project-based methods and males finding project-based learning enjoyable and beneficial.

In the next chapter, the analyses and findings of this chapter are discussed in more detail and the contributions and limitations of this study are also discussed. Suggestions for further research are also included in the next chapter.

Chapter 5

SUMMARY AND CONCLUSION

5.1 Introduction

This final chapter provides a summary of my major findings with the aim of drawing a conclusion for each of the research questions provided in Chapter 1. In the context of this research, the significance, implications and limitations of my study are elaborated and recommendations for further research are suggested.

The final chapter of this thesis covers the following headings:

- Summary of the Thesis (Section 5.2)
- Major Findings of the Study (Section 5.3)
- Significance and Implications (Section 5.4)
- Limitations of the Study (Section 5.5)
- Recommendations for Further Research (Section 5.6)
- Summary and Final Comments (Section 5.7).

5.2 Summary of the Thesis

This thesis contains five chapters with Chapter 1 providing the rationale for the study including the four major research questions:

- Is it possible to modify and validate a questionnaire based on the WIHIC and attitude and efficacy scales for use with first-year high-school students in Adelaide, South Australia?
- Is project-based mathematics effective for first-year high-school students' in terms of learning environment, attitude, academic efficacy and achievement?
- Is project-based learning differentially effective for females and males in terms of learning environment, attitude, academic efficacy and achievement?
- Are there associations between learning environment and student attitudes, academic efficacy and achievement?

Chapter 1 provided a brief rationale for this research in the context of the current challenges in mathematics education in Australia. It covered the theoretical framework for the study which was underpinned by the field of learning environments. It outlines the basis for using the What Is Happening In this Class? (WIHIC) instrument coupled with a modified scale from the Test of Science Related Attitudes (TOSRA) and the Morgan-Jinks Student Efficacy scale (MJSES). The significance of the study was identified and the chapter concluded with an overview of the various chapters of the thesis.

Chapter 2 reviewed literature related to this study, beginning with an in-depth historical focus on the field of learning environments and followed by a detailed discussion of instruments for assessing learning environments. In reviewing the learning environment instruments, this section drew on significant research that has been conducted across many countries and in different cultural contexts. Primarily, it focussed on the WIHIC. In addition, this chapter included a detailed review of students' attitudes, academic efficacy, sex-related differences, and research into project-based learning.

Chapter 3 provided information about my research methodology which followed an explanatory mixed-methods approach, combining quantitative and qualitative research methods. A questionnaire based on the seven scales of the WIHIC, an Attitude to Subject scale modified from the TOSRA and the Morgan-Jinks Self Efficacy scale was administered to 10 classes in a high school in South Australia. The sample consisted of total of 284 students of whom 192 students in 7 classes followed a project-based mathematics curriculum and 92 students in 3 classes followed a traditional mathematics curriculum. In addition to the quantitative data, qualitative data (observations and interviews) were collected to allow triangulation and establish emerging themes to provide an explanation for the findings from the quantitative part of my study. This chapter concluded with a detailed explanation of the methods for data analysis for each specific research question and the ethical considerations required in this study.

Chapter 4 reported the findings based on the quantitative data which were analysed using numerous statistical methods to answer the research questions. In order to address the validity and reliability of the scales in my study, principal axis factoring with varimax rotation and Kaiser normalization was used. Cronbach's alpha coefficient was used to check reliability and ANOVA was used to check whether learning environment scales differentiated between classrooms. A two-way MANOVA was used to determine if project-based mathematics was effective and whether project-based mathematics was differentially effective for males and females. To answer the final research question, in relation to associations between learning environment and student outcomes, simple correlation and multiple regression analyses was used. The qualitative data section provided tentative explanations for the quantitative results and embellished and supported the findings based on the quantitative methods. The results from Chapter 4 are summarised in more detail in Section 5.3 of this chapter.

Chapter 5 provides a summary and conclusion to this study. It provides an overview and the major findings of the thesis. It also details the significance, implications and limitations of the study, as well as suggesting recommendations for further research. This chapter concludes with a summary and final comment.

5.3 Major Findings of the Study

5.3.1 *Research Question 1: Is it possible to modify and validate a questionnaire based on the WIHIC and attitude and efficacy scales for use with first-year high-school students in Adelaide, South Australia?*

A pretest questionnaire consisting of 7 scales from the WIHIC and a modified Attitude to Subject scale from the TOSRA and the Morgan-Jinks Self Efficacy scale was administered to 284 students in 7 project-based and 3 non-project-based classes approximately 6 weeks into the academic year and again as a posttest at the conclusion of my study. Statistical analyses of the learning environment and attitude data were undertaken to examine the factorial validity, scale internal consistency (alpha reliability coefficient) and ability to differentiate between classes.

Principal axis factoring with varimax rotation and Kaiser normalization was conducted

separately for each questionnaire (learning environment and attitude/efficacy) and separately for pretest and posttest data. Key findings are summarised below:

- One item from Student Cohesiveness, two items from Involvement and one item from Academic Efficacy were removed following the application of the criteria that any item must have a factor loading of at least 0.40 with its own scale and less than 0.40 with every other scale in the same questionnaire.
- After removal of these four items, the *a priori* seven-scale structure of the WIHIC and the two-scale structure of the attitude/efficacy questionnaire were replicated perfectly.
- Factor analysis of the data revealed that the total proportion of variance accounted for by the seven WIHIC scales was 63.37% for the pretest and 71.58% for the posttest. The scale eigenvalues for the WIHIC ranged from 1.25 to 16.32 for the pretest and 1.43 to 21.55 for the posttest.
- For the attitude/efficacy scales, the total proportion of variance was 70.82% for the pretest and 76.81% for the posttest. The scale eigenvalues ranged from 2.6 to 8.02 for the pretest and 2.6 to 8.9 for the posttest.
- The internal consistency reliability of each WIHIC and attitude scale was calculated separately for pretest and posttest data and separately for two units of analysis (the student and the class mean) using Cronbach's alpha coefficient. For the posttest, alpha coefficients for the nine scales ranged from 0.87 to 0.97 with the student as the unit of analysis and from 0.83 to 0.98 with the class as the unit of analysis.
- When analysis of variance (ANOVA) was conducted for each learning environment scale, with class membership as the independent variable, it was found that nearly every WIHIC scale could differentiate significantly between the perceptions of students in different classrooms. Eta² values ranged from 0.12 to 0.33 for the pretest and 0.12 to 0.37 for the posttest. Six scales for the pretest and 5 scales for the posttest were able to differentiate significantly ($p < 0.01$) between the 10 mathematics classes.

The results supported the strong factorial validity of the final 68-item, 9-scale version of the questionnaire when used with a sample of first-year high-school students in

South Australia. Over the last 20 years, the WIHIC has been shown to be valid and reliable in many studies across many countries and it has become the most-frequently used classroom instrument in the world today (Fraser, 2014). Large cross-national studies involving the WIHIC were conducted by Aldridge, Fraser and Huang (1999), Aldridge and Fraser (2000), Dorman (2003) and Fraser, Aldridge and Adolphe (2010). The WIHIC has been used in conjunction with scales from other instruments such as the TOSRA and Morgan-Jinks Efficacy scale, which have been found to be valid and useful in previous studies at various grade levels, in various languages and in many countries across the world (Zandvliet & Fraser, 2004, 2005; Chionh & Fraser, 2009; Margianti, Fraser & Aldridge, 2001; MacLeod & Fraser, 2010). More recently, studies by Afari, Aldridge, Fraser and Khine (2013), Peer and Fraser (2015), Cohn and Fraser (2016) and Long and Fraser (2015) have reported strong factorial validity and internal consistency reliability, which attests to the usefulness and versatility of the WIHIC in learning environments research. The results for Research Question 1 provided strong evidence in support of the validity and reliability of my survey instrument, in terms of factor structure, internal consistency reliability and ability to differentiate between classrooms. Therefore, it was appropriate to use it as my main survey instrument for the purposes of this study.

5.3.2 Research Question 2: Is Project-based Mathematics Effective for First-year High-school Students in terms of Learning Environment, Attitude, Academic Efficacy and Achievement?

Research Question 3: Is Project-based Mathematics Differentially Effective for Females and Males in terms of Learning Environment, Attitude, Academic Efficacy and Achievement?

The second research question focused on a comparison of the project group with the non-project group in terms of learning environment, attitude, efficacy and achievement scales. The third research question involved whether any differences existing between instructional methods were similar or different for female and male students.

5.3.2.1 Quantitative Analysis

By conducting a two-way MANOVA with my whole sample of 284 students, the seven WIHIC learning environment, two attitude/efficacy scales and one achievement scale

as a set of 10 dependent variables, both my second and third research questions were investigated simultaneously. The two independent variables were instructional method and student sex. The presence or absence of a statistically significant interaction between instructional method and sex was used to identify whether instructional-method differences were different or similar for males and females. The following key findings are summarised below:

- Using Wilks' lambda criterion, MANOVA revealed statistically significant multivariate results for instructional method ($F = 2.46, p < 0.01$), sex ($F = 2.16, p < 0.05$) and the instruction-by-sex interaction ($F = 2.10, p < 0.05$).
- Statistically significant results emerged from ANOVA's for: instructional method for one learning environment scale (Equity) and for Achievement; and for sex for one learning environment scale (Cooperation) and for (Attitude to Subject). The instruction-by-sex interaction was statistically significant for one learning environment scale (Teacher Support) and for both attitude scales of Attitude to Subject and Academic Efficacy.
- For the 10 scales, mean scores were somewhat less favourable for the project group for five of the seven learning environment scales, more favourable for the project group for both attitude/efficacy scales and less favourable for the project group for achievement. However, for most scales, these differences between project and non-project students were both small and statistically non-significant.
- Relative to non-project students, project students perceived a significantly less positive classroom environment for Equity and had significantly lower achievement scores. For these two scales, there was a small effect size of 0.26 standard deviations for Equity and a modest effect size of 0.44 standard deviations for Achievement.
- Because of the existence of significant instruction-by-sex interactions for three scales, instructional-method differences for these three scales (Teacher Support, Attitude to Subject and Academic Efficacy) were revisited. This suggests that the interpretation of results separately for instructional method and sex were not valid and meaningful and needed to be modified in the case

of these three scales.

- Further analyses using the mean and standard deviation for each scale for four subsamples (project-based males, project-based females, non-project-based males and non-project-based females) showed an interesting pattern in the sign/direction of sex differences for the project group relative to the non-project group. For most scales, males scored somewhat more highly than females in the project group, but females scored somewhat more highly than males in the non-project group. Although these differences typically were small in magnitude and the instruction-by-sex interaction was non-significant, still the pattern of results suggested that the project method was differentially effective for males and females, with males benefitting more from the project approach and females benefiting more from traditional (non-project) methods (see Figures 4.1, 4.2 and 4.3).
- By simultaneously considering Table 4.9 and Figures 4.1, 4.2 and 4.3, the following refined interpretations emerged:
 - Teacher Support scores were not significantly different either for different instructional methods or for different sexes, but males benefitted more from the project approach whereas females benefitted more from traditional methods.
 - Attitude to Subject scores were not significantly different for different instructional methods, but females scored significantly more highly than males. Nevertheless, females' attitude to mathematics was more positive under the traditional non-project method, whereas males' attitude to mathematics was similar under either instructional method.
 - Academic Efficacy scores were not significantly different either for different instructional methods or for different sexes, but males benefitted more from the project approach whereas females benefitted more from traditional methods.

5.3.2.2 *Qualitative Analysis*

A key finding from my study based on quantitative data was that project-based

mathematics was differentially effective for females and males for the learning environment scale of Teacher Support and Attitude to Subject and Academic Efficacy scales. Although scores were not significantly different between instructional methods, a pattern emerged in which females preferred and benefitted more from a traditional approach and males benefitting more from a project-based approach. Qualitative data analyses were used to explain student perceptions of Teacher Support, Attitude to Subject and Academic Efficacy and specifically sex-related differences.

Analyses focussed on three themes:

- a. Pedagogy of project-based learning and the role of the teacher
- b. Sex-related differences in project-based learning
- c. Attitude and academic efficacy in project-based learning.

It was evident from observations that project-based learning requires a different approach to pedagogy. Teachers were more intimately involved in scaffolding the initial stages of project-based learning, with students being more dependent on their teacher compared with non-project-based classes. The role of the teacher was considered significant especially in terms of Teacher Support. In other studies involving educational innovations, similar findings involving Teacher Support were reported (Afari, Aldridge, Fraser & Khine, 2012; Wong, 2016).

It was also evident from the qualitative data that students enjoyed the experience of project-based learning but it brought a new challenge in the context of students' mathematical thinking and understanding. Project-based learning involves a range of new experiences which include working successfully in groups, ensuring equity in terms of effort from all group members, focusing on task because of distractions, understanding relevance in terms of curriculum and catering for different mathematical abilities within groups. However, the challenges in project-based learning did not deter from the students' endeavour and commitment. Qualitative information supported and embellished the quantitative findings and provided an explanation of why female students preferred traditional methods compared with project-based methods and why males preferred project-based methods compared with traditional methods. Whilst both males and females enjoyed the change from traditional methods to project-based

methods, females were not convinced of the relevance and efficacy of a project-based approach to learning mathematics. Females tended to find the approach confusing and became anxious about not being able to complete tasks to a high standard. On the other hand, males typically enjoyed the project-based approach, were motivated and interested in the applied nature of the tasks, working in teams and working in a climate of autonomy.

Sex-related differences were evident and consistent with past studies which have reported significant differences between males and females (Fennema & Sherman, 1978). In a study by Ferguson and Fraser (1998), significant sex-related differences were found when students' transitioned from primary school to high school, which is similar to my study. Because typically females are more relationship oriented and males are more activity-task oriented, students of different genders are likely to report differently in terms of attitudes and Teacher Support.

5.3.3 Research Question 4: Are There Associations between Learning Environment and Student Attitudes, Academic Efficacy and Achievement?

The fourth research question focused on associations between the dimensions of the learning environment and the student outcomes of attitudes, academic efficacy and achievement. Associations between three student outcomes (Attitude to Subject, Academic Efficacy and Achievement) and the 7 classroom learning environment scales of the WIHIC were examined for my sample of 284 students. A simple correlation analysis was used for examining the bivariate association between each learning environment scale and each student outcome. A multiple regression analysis was used for each outcome to provide information about the multivariate association between each student outcome and the set of 7 learning environment scales. The regression coefficient was used to identify which learning environment scales contributed to variance in student outcomes when all other learning environment scales were mutually controlled.

With the individual student as the unit of analysis, all seven learning environment scales of the WIHIC were correlated positively and significantly ($p < 0.01$) with Attitude to Subject. The simple correlation analysis suggested a bivariate association

between Attitude to Subject and a greater emphasis on all of the learning environment scales.

The multiple correlation (R) reported between the 7 learning environment scales and the Attitude to Subject scale at the individual student level of analysis was 0.63 and was statistically significant ($p < 0.01$). In considering the standardised regression weights to provide information about which of the seven learning environment scales of the WIHIC uniquely contributed to the variance in the Attitude to Subject scale when the other learning environment scales were mutually controlled, associations were statistically significant ($p < 0.05$) for three WIHIC scales (Teacher Support, Investigation and Task Orientation).

The simple correlation analysis revealed that all seven of the learning environment scales of the WIHIC were correlated positively and significantly ($p < 0.01$) with the Academic Efficacy scale. The multiple correlation (R) between the 7 learning environment scales and the Academic Efficacy scale was 0.65 and was statistically significant ($p < 0.01$). When the standardised regression weights were used to provide information about which of the seven learning environment scales of the WIHIC contributed uniquely to the variance in the Academic Efficacy scale when the other learning environment scales were mutually controlled, associations were statistically significant ($p < 0.01$) for three WIHIC scales (Involvement, Investigation and Task Orientation).

My study also considered whether associations existed between dimensions of the learning environment and achievement, which was measured with a mathematics test. The simple correlation analysis showed that four of the learning environment scales (Involvement, Investigation, Task Orientation and Equity) of the WIHIC were correlated positively and significantly ($p < 0.01$) with Achievement. The multiple correlation (R) between the 7 learning environment scales and Achievement was 0.30 and was statistically significant ($p < 0.01$). Examining the standardised regression weights revealed that one WIHIC scale (Task Orientation) was a statistically-significant ($p < 0.05$) independent predictor of achievement.

All statistically significant relationships were positive for both the simple correlation

and multiple regression analyses, suggesting a positive association between Attitude to Subject, Academic Efficacy, Achievement and the dimensions of learning environment.

The findings from my study are aligned with similar findings from many past studies which have reported positive associations between environment and attitudes, academic efficacy and achievement (Afari et al., 2015; Aldridge & Fraser, 2009; Chionh & Fraser, 2009; Dorman & Fraser, 2009; Fraser, Aldridge & Adolphe, 2010; Wolf & Fraser, 2008).

5.4 Significance and Implications

The study contributes to the field of learning environments and is significant for four reasons. First, the study is unique in terms of validating a questionnaire based on the WIHIC and Attitude to Subject scale from the TOSRA and the Academic Efficacy scale from the MJSES with first-year high-school students in South Australia. It adds weight to past learning environment research and is consistent with many past studies which have utilised similar instruments.

Second, past studies evaluating the effectiveness of project-based learning in mathematics using learning environment criteria are limited, particularly in the early stages of high school, and investigations of the differential effectiveness of project-based mathematics for males and females in terms of their perceptions of their learning environment are novel. There is a body of research related to brain theory which seeks reasons for differences between male and female children's experiences in relation to project-based learning. This has implications for STEM learning and the instructional strategies used (Baron-Cohen, 2004). Therefore this research could offer insights into the differentiated learning preferences of males and females.

Third, it is likely to have implications for teaching practice, especially how a new teaching strategy can impact the learning environment, attitude to mathematics, academic efficacy and achievement. Because schools are constantly looking to improve student engagement and learning outcomes, teachers question whether using innovative new strategies can have a different impact on males and females.

For example, the use of the instruments in this study could inform teachers about their students' perceptions of their learning environment, their associations with attitudes, academic efficacy and achievement, and how a teacher might implement accommodations specifically for males and females. It could provide teachers with the opportunity to reflect on their own practice and assess how different pedagogies could lead to more positive student outcomes.

Finally, this study is distinctive because it combined multiple research methods to provide a legitimate inquiry approach as recommended by Brewer and Hunter (1989) and Creswell (2008).

5.5 Limitations of the Study

It is acknowledged that prior to and during the study a number of limitations and constraints were considered and encountered. This section considers these limitations and constraints and the subsequent decisions and actions that were taken to minimise their effect on my study.

The first challenge was the size and composition of the sample for my study of the effectiveness of project-based mathematics in terms of learning environment, attitudes, academic efficacy and achievement. Because project-based learning can be broad and varied and in order to ensure that the project-based approach was similar and consistent for the whole sample, the study was conducted in one school with the entire student body in their first year of high school ($N=192$) and a comparison sample ($N=92$) which followed a traditional approach. Although the sample in this study was relatively small in comparison with some other studies of learning environments (Fraser, 2014), capturing the entire student body in the first year of high school was advantageous. Because of potential limitations with the sample size, active follow up with parental consent (98% permission) and a high completion rate for the survey (90% completed) ensured that the final sample size was still reasonable for this study.

Because the selected sample was limited to one school, findings in this study should not be generalised to all students in their first year of high school. Indeed, a sample comprising different schools from different educational sectors, including co-

educational and single-sex settings, would be desirable in future research. Because larger samples lead to greater statistical power for analyses and higher validity regarding the inferences drawn from research (Creswell, 2008), a more comprehensive sample in my study might have produced more dependable findings.

Random sampling is desirable in educational research (Creswell, 2008) and it is acknowledged that, in this study, the choice of school and the use of the whole first-year high-school cohort did not lead to a random sample. However, the sample of students used in the qualitative section of the study was randomly selected.

The survey involved an on-line tool to minimise inaccuracies such as non-completion of questions. The achievement test was also developed as an on-line tool that required students to select from a range of multiple-choice answers. Significant challenges were encountered by the researcher, such as student fatigue which was minimised by testing in the morning, students having had little experience with involvement in research, and high levels of anxiety because of technological challenges, and a desire to do well. Considering these limitations, my study still achieved a reasonable sample size for quantitative analyses and, coupled with qualitative approaches, allowed discrepancies in the data to be further explored.

Because project-based strategies in mathematics are not mandated in South Australian schools, project-based tasks can range in complexity from simple practical activities to major student-directed projects. As teachers involved in the study had limited experience in major student-directed projects, the researcher needed to facilitate professional development to ensure that the quality of the project-based activities was similar for all students involved in the study. Teachers involved in this study ranged from very experienced mathematics teachers to early-career middle-school teachers. Although this was considered to be a limitation at the beginning of the study, professional development, support and supervision were provided by the school to ensure the quality of curriculum delivery.

Although the research involved a mixed-methods approach, the qualitative part was relatively small and comprised semi-structured interviews with a random sample of students ($n=28$) and staff ($n=3$) following the posttest survey. Whilst the study also

included observation of some classes, ideally the qualitative component would have been more comprehensive in terms of observations and interviews at the beginning and end of the study; however, because of the number of the school's request to minimise intrusion in the classroom, the qualitative component was limited.

5.6 Recommendations for Further Research

The limitations identified in Section 5.4 naturally lead to recommendations for potential further research. Future research into the effectiveness of problem-based learning across a range of subject disciplines and schools from different geographic areas would increase the sample's size and diversity and therefore the capacity to conduct a more-thorough statistical analyses and lead to greater confidence in the subsequent findings.

A mixed-method design which follows an explorative approach and uses qualitative data to prepare for quantitative data collection (Creswell, 2008) could provide greater insight at the beginning of a study into the learning environment context and setting, prior to implementing project-based learning. Explanatory qualitative data collection and analysis after the completion of the study could provide further insights.

A mixed-methods study involving similar survey tools, but using both actual and preferred forms of the WIHIC, would provide additional understanding about the effectiveness of project-based learning in terms differences between actual and preferred classroom learning environments.

In deciding which students should be surveyed and involved in a study of project-based learning, it was decided to focus on first-year high-school students who would be new to a high-school learning environment context and who had not yet been enculturated by a high-school learning method which is heavily weighted to direct and explicit instruction. Whilst factors which can affect learning during transition between levels of schooling are well documented (Attard, 2010; Ferguson & Fraser, 1998; Speering & Rennie, 1996), these were not considered in this study. Investigating factors that can affect student preferences and confidence during transition is a potential extension to this study.

As reported in Section 5.4 on the significance and implications of my study, research into the differential effectiveness of project-based mathematics for males and females is limited. Expanding this study to encompass research on project-based learning and direct and explicit instruction would be useful, especially if it included brain theory during the developmental stages of children.

5.7 Summary and Final Comments

Qualitative data generally supported findings based on quantitative surveys concerning the differential effectiveness of project-based mathematics for males and females. Females primarily questioned the purpose of project-based learning and found it somewhat confusing, difficult to make mathematical connections, and detrimental to their academic progress in the context of high academic expectations. On the other hand, females enjoyed this approach as a break from their traditional learning. Males reported that project-based learning was beneficial and that they enjoyed group work, involvement, challenge and the choice of activities. Males generally enjoyed the practical tasks and connections to new learning and were less concerned about academic progress.

Many students had difficulty with the unstructured and open-ended nature of project-based activities, but they enjoyed the change from the more traditional procedural mathematics and textbook learning. Project-based mathematics was new to students and working in groups provided significant challenges for many of them.

In the field of learning environments, this study is unique because of the limited number of past studies into the effectiveness of project-based learning in mathematics in the first year of high school in terms of learning environment, attitudes, academic efficacy and achievement. This research contributes to both the field of learning environments and to an understanding of the pedagogy of project-based mathematics. Findings concerning the differential effectiveness of project-based mathematics for males and females are noteworthy and hopefully provide new insights into the effective use of project-based strategies in mathematics for both males and females.

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APPENDIX A

STUDENT QUESTIONNAIRE BASED OF THE WIHIC, ATTITUDE TO
SUBJECT SCALE FROM THE TOSRA AND THE MORGAN-JINKS EFFICACY
SCALE

MIDDLE SCHOOL MATHEMATICS SURVEY

Learning Environment Survey based on WIHIC with Attitude/Efficacy Scales

1. Please enter your student mathematics number which is provided for you

Student number

2. Gender

☐ Male ☐ Female

Directions for students

This questionnaire contains statements about practices which took place in your mathematics class this TERM. You will be asked how often each practice took place.

There are no right or wrong answers. Your opinion is what is wanted. Think about how well each statement describes what this class was like for you.

- 1 If the practice takes place Almost Never
- 2 If the practice takes place Seldom
- 3 If the practice takes place Sometimes
- 4 If the practice takes place Often
- 5 If the practice takes place Almost Always

Be sure to give an answer for all questions. Some statements in this questionnaire are similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Practice Example

Suppose that you were given the statement: "I choose my partners for group discussion." You would need to decide the extent to which you agree with the statement that you can choose your partners.

For example, if you selected Almost Always, you would click the number 5.

LEARNING ENVIRONMENT

* 3. STUDENT COHESION

	Almost Never	Seldom	Sometimes	Often	Almost Always
*I make friendships among students in this class.	1	2	3	4	5
*I know other students in this class.	1	2	3	4	5
*I am friendly to members of this class.	1	2	3	4	5
*Members of this class are my friends.	1	2	3	4	5
*I work well with other class members.	1	2	3	4	5
*I help other class members who are having trouble with their work.	1	2	3	4	5
*Students in this class like me.	1	2	3	4	5
*In this class I get help from other students.	1	2	3	4	5

* 4. TEACHING SUPPORT

	Almost Never	Seldom	Sometimes	Often	Almost Always
*The teacher goes out of his/her way to help me.	1	2	3	4	5
*The teacher helps me when I have trouble with the work.	1	2	3	4	5
*The teacher is interested in my problems.	1	2	3	4	5
*The teacher's questions help me to understand.	1	2	3	4	5
*The teacher goes out of his/her way to help me.	1	2	3	4	5
*The teacher helps me when I have trouble with the work.	1	2	3	4	5
*The teacher is interested in my problems.	1	2	3	4	5
*The teacher's questions help me to understand.	1	2	3	4	5

*** 5. INVOLVEMENT**

	Almost Never	Seldom	Sometimes	Often	Almost Always
*I discuss ideas in class.	1	2	3	4	5
*I give my opinions during class discussions.	1	2	3	4	5
*The teacher asks me questions.	1	2	3	4	5
*My ideas & suggestions are used during classroom discussions.	1	2	3	4	5
*I ask the teacher questions.	1	2	3	4	5
*I explain my ideas to other students.	1	2	3	4	5
*Students discuss with me how to go about solving problems.	1	2	3	4	5
*I am asked to explain how to solve problems.	1	2	3	4	5

*** 6. INVESTIGATION**

	Almost Never	Seldom	Sometimes	Often	Almost Always
*I carry out investigations to test my ideas.	1	2	3	4	5
*I am asked to think about the evidence for statements.	1	2	3	4	5
*I carry out investigations to answer questions coming from discussions.	1	2	3	4	5
*I explain the meaning of statements, diagrams and graphs.	1	2	3	4	5
*I carry out investigations to answer questions which puzzle me.	1	2	3	4	5
*I carry out investigations to answer the teacher's questions.	1	2	3	4	5
*I find out answers to questions by doing investigations.	1	2	3	4	5
*I solve problems using information obtained from my own investigations.	1	2	3	4	5

*** 7. TASK ORIENTATION**

	Almost Never	Seldom	Sometimes	Often	Almost Always
*Getting a certain amount of work done is important to me.	1	2	3	4	5
*I do as much as I set out to do.	1	2	3	4	5
*I know the goals for this class.	1	2	3	4	5
*I am ready to start this class on time.	1	2	3	4	5
*I know what I am trying to accomplish in this class.	1	2	3	4	5
*I pay attention during this class.	1	2	3	4	5
*I try to understand the work in this class.	1	2	3	4	5
*I know how much work I have to do.	1	2	3	4	5

*** 8. COOPERATION**

	Almost Never	Seldom	Sometimes	Often	Almost Always
*I cooperate with other students when doing assignment work.	1	2	3	4	5
*I share my books and resources with other students when doing assignments.	1	2	3	4	5
*When I work in groups in this class, there is teamwork.	1	2	3	4	5
*I work with other students on projects class.	1	2	3	4	5
*I learn from other students in this class.	1	2	3	4	5
*I work with other students in this class.	1	2	3	4	5
*I cooperate with other students on class activities.	1	2	3	4	5
*Students work with me to achieve class goals.	1	2	3	4	5

*** 9. EQUITY**

	Almost Never	Seldom	Sometimes	Often	Almost Always
*The teacher gives me as much attention to my question as to other student's questions.	1	2	3	4	5
*I get the same amount of help from the teacher as other students.	1	2	3	4	5
*I have the same amount of say in this class as other students.	1	2	3	4	5
*I am treated the same as other students in the class.	1	2	3	4	5
*I receive the same encouragement from the teacher as other students do.	1	2	3	4	5
*I get the same opportunity to contribute to class discussions as other students.	1	2	3	4	5
*My work receives as much praise as other student's work.	1	2	3	4	5
*I get the same opportunity to answer questions as other students.	1	2	3	4	5

ATTITUDE AND ACADEMIC EFFICACY

This questionnaire contains statements about how you feel about this subject. You will be asked how often you feel this way. There are no 'right' or wrong answers. Your opinion is what is wanted. Think about how well each statement describes what this class is like for you.

- 1 If you feel this way Almost Never
- 2 If you feel this way Seldom
- 3 If you feel this way Sometimes
- 4 If you feel this way Often
- 5 If you feel this way Almost Always

Be sure to give an answer for all questions.

* 10. ATTITUDE TO SUBJECT

	Almost Never	Seldom	Sometimes	Often	Almost Always
*I look forward to lessons in this subject.	1	2	3	4	5
*Lessons in this subject are fun.	1	2	3	4	5
*I like lessons in this subject.	1	2	3	4	5
*Lessons in this subject excite me.	1	2	3	4	5
*This subject is one of the most interesting subjects.	1	2	3	4	5
*I enjoy lessons in this subject.	1	2	3	4	5
*Lessons in this subject are worthwhile.	1	2	3	4	5
*These lessons make me interested in this subject.	1	2	3	4	5

*** 11. ACADEMIC EFFICACY**

	Almost Never	Seldom	Sometimes	Often	Almost Always
*I find it easy to get good grades in this subject.	1	2	3	4	5
*I am good at this subject.	1	2	3	4	5
*My friends ask me for help in this subject.	1	2	3	4	5
*I find this subject easy.	1	2	3	4	5
*I outdo most of my classmates in this subject.	1	2	3	4	5
*I have to work hard to pass this subject.	1	2	3	4	5
*I am an intelligent student.	1	2	3	4	5
*I help my friends with their homework in this subject.	1	2	3	4	5

APPENDIX B

SAMPLE QUESTIONS FROM THE ACHIEVEMENT TEST

YEAR 8 STUDENT ACHIEVEMENT TEST

Q1. Simplify $-3(-8 - +2)$

A: -18

B: $+18$

C: $+22$

D: -30

E: $+30$

Q2. These students have been asked to estimate 38×62 .



Reuben

My calculator got 2356, so that's my estimate.



Connor

My estimate is 2356 because I worked out 38×62 .



Mia

I multiplied the numbers to get 2356, then I rounded it down to 2350.



Liam

$40 \times 60 = 2400$, so that's my estimate.



Sophia

I did 2×3635286

So that's my estimate.

Which student has used an estimation method?

Q3. Which one of these sentences is true?

A: $28 > 8$

B: $48 < 5$

C: $9 = 3$

D: $25 = 125$

E: $24 > 9$

Q4. A jacket that cost \$80 is reduced in a sale to \$64.



By what percentage has the jacket been reduced?

A: 16%

B: 20%

C: 25%

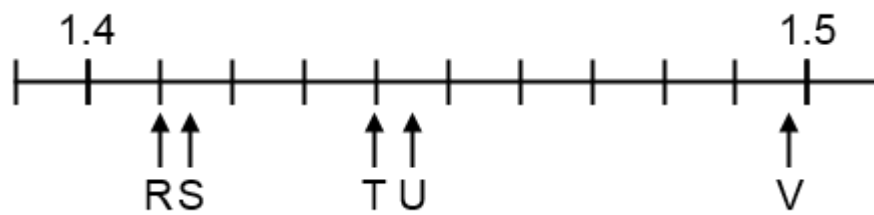
D: 36%

E: none of these

Q5. Eli uses the square root key on his calculator to find $\sqrt{2}$.

The calculator display shows 1.4142135623.

Eli wants to place this number on his number line as accurately as possible.



Where should he place it?

A: R

B: S

C: T

D: U

E: V

Q6. 317 people are coming to the school's quiz night.



If each table can seat 8 people, what is the smallest number of tables that will be needed?

A: 36

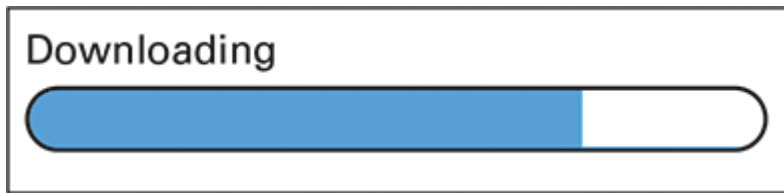
B: 37

C: 38

D: 39

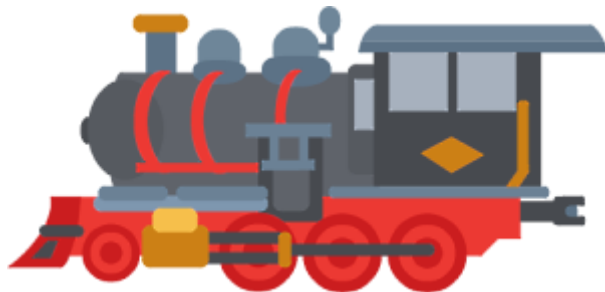
E: 40

Q7. A computer program uses a shaded bar to show how much of a file has been downloaded from the Internet.



If the total file size is 2 megabytes, how much has been downloaded so far?

- A: 0.75 megabytes
 - B: 1.05 megabytes
 - C: 1.25 megabytes
 - D: 1.5 megabytes
 - E: 1.75 megabytes
- Q8. A warehouse buys televisions for a cost price of \$640 each.
The warehouse then sells the televisions for \$960 each.
Find the profit on each television as a percentage of its cost price.
- A: 66 %
 - B: 50%
 - C: 40%
 - D: 33%
 - E: 20%
- Q9. A train travels 1 kilometre in 1 minute 20 seconds.



At this rate, how many kilometres will the train travel in 1 hour?

- A: 40 km

B: 45 km

C: 48 km

D: 72 km

E: 75 km

APPENDIX C

SAMPLE OF INTERVIEW QUESTIONS STUDENTS

AND TEACHERS

THE EFFECTIVENESS OF PROJECT-BASED MATHEMATICS IN THE FIRST YEAR OF HIGH SCHOOL IN TERMS OF LEARNING ENVIRONMENT, ATTITUDE, ACADEMIC EFFICACY AND ACHIEVEMENT

Interview Questions for students

1. Tell me what you really enjoyed about participating in your project-based mathematics activity?
2. Tell me what you found really challenging in your project-based mathematics activity?
3. Tell me a bit more about your class, do you know each other well, do you help each other, do you work well together, do you get help from your friends?
4. Tell me a bit about your teacher, do you get on well with your teacher, does he/she help you out and show interest in you?
5. In your project-based activity did you discuss your ideas and did you work together to solve problems?
6. When you were involved in your activity did you use investigations to solve your issues and questions and did you discuss these?
7. Share with me how you completed your tasks; did you have to do a certain amount of work? Did you do more?
8. Project-based mathematics required you to work in a team, did find that your team mates were cooperative? Did they share and contribute equally?
9. How do you find this activity in comparison with other mathematics activities you have experienced?
10. Do you feel confident that you have achieved what you set out to achieve?
11. Do you have any other comments which you would like to raise?

Interview Questions for participating teachers?

1. Can you share with me the high points of this activity with respect to meeting your teaching objectives and student learning outcomes?
2. Can you share the challenges you experienced with respect to your teaching objectives and student learning outcomes?
3. Can you share with me how you observed your class in terms of the learning

environment scales, attitude to subject, academic efficacy and achievement?

4. What did you observe as the specific strength of this approach in meeting student outcomes?
5. Are there any other points you might want to add in support or other in terms of your experience?
6. Do you have any other comments which you would like to raise?

APPENDIX D
OBSERVATION TEMPLATE

THE EFFECTIVENESS OF PROJECT-BASED MATHEMATICS IN THE FIRST YEAR OF HIGH SCHOOL IN TERMS OF LEARNING ENVIRONMENT, ATTITUDE, ACADEMIC EFFICACY AND ACHIEVEMENT

Classroom Observation Checklist

The observer will observe the classroom during a lesson when students are engaged in their project-based mathematics activity. Using a checklist of number of observances in the classroom will be noted in:

- **Student Cohesiveness**
 - Interactions between students (positive or negative)
- **Teacher support**
 - Teacher/student interactions
 - Individual student interactions
 - Teacher response to questions
 - Teacher response to assistance required
- **Involvement**
 - Student-student
 - Teacher-student
- **Investigation**
 - Students using investigation
 - Teacher directing investigation
 - Student response
- **Task Orientation**
 - Are students on task
 - Are they productive
 - Level of engagement
- **Cooperation**
 - Level of engagement with students in teams
 - Cooperation
 - Focus on task and support
- **Equity**
 - Teacher involves all students
 - Teacher listening to students
 - Teacher – student interactions

APPENDIX E

PARTICIPANT INFORMATION SHEET

Science Mathematics Education Centre

Participant's Information Sheet

My name is Paul Rijken. I am currently completing a piece of research for my Doctorate of Philosophy in Mathematics Education at Curtin University.

Purpose of Research

The research I am conducting is in the area of Mathematics and seeks to investigate the effectiveness of a project-based strategy to enhance learning in the area of Learning Environment, Attitude, Academic Efficacy and Achievement. I am interested in finding out from you what happens in the classroom with respect to your mathematics learning. This also includes your attitude to mathematics and how you feel about it.

I will ask you to complete a questionnaire which will be given to you at the start of your project-based mathematics work and then again at the end of your experience. It will take no more than 25 minutes to complete and will be multiple choice.

Consent to Participate

Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. Whether you choose to participate in the study or not, you will not be penalised, and your marks will not be affected in any way.

When you have signed the consent form and your parents/guardian has also signed the consent form, I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentially

The information you provide will be kept separate from your personal details, and only myself and my supervisor will have access to this. Your class or school will not be identified. The questionnaire will not have your name except a code which links your first questionnaire with your second questionnaire. In adherence with the university policy, the questionnaires will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information

This study was approved under Curtin University's process for lower risk studies (Approval Number SMEC-48-12). This process complies with the National Statement on Ethical Conduct in Human Research (Chp 5.1.7 and Chps 5.1.18-5.1.21). If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, WA 6845 or by telephoning (08) 9266 2784 or by emailing hrec@curtin.edu.au

If you would like further information about the study, please feel free to contact me on (08) 8392 9577 or by email paul.rijken@postgrad.curtin.edu.au. Alternatively, you can contact my supervisor Professor Barry Fraser on (08) 89266 7896 or email B.Fraser@curtin.edu.au

Thank you very much for your involvement in this research.

Your participation is greatly appreciated

A handwritten signature in blue ink, appearing to be 'P. Rijken', with a stylized flourish at the end.

Paul Rijken

Post Graduate Research Student

Curtin University

APPENDIX F
STUDENT CONSENT FORM

Science Mathematics Education Centre

THE EFFECTIVENESS OF PROJECT-BASED MATHEMATICS IN THE FIRST YEAR OF HIGH SCHOOL IN TERMS OF LEARNING ENVIRONMENT, ACADEMIC EFFICACY AND ACHIEVEMENT

- I understand the purpose and procedures of the study.
- I have been provided with the participation information sheet.
- I understand that the procedure itself may not benefit me.
- I understand that my involvement is voluntary and I can withdraw at any time without problem.
- I understand that no personal identifying information like my name and address will be used in any published materials.
- I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.
- I have been given the opportunity to ask questions about this research.
- I agree to participate in the study outlined to me

Participant's name:

Participant's signature:

Date:.....

Parent/Guardian Name:.....

Parent/Guardian Signature:.....

Date:.....

APPENDIX G

CURTIN UNIVERSITY ETHICS APPROVAL

Memorandum

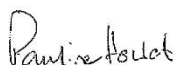
To	Paul Rijken, SMEC
From	Pauline Howat, Administrator, Human Research Ethics Science and Mathematics Education Centre
Subject	Protocol Approval SMEC-48-12
Date	12 December 2012
Copy	Barry Fraser, SMEC

Office of Research and Development
Human Research Ethics Committee
Telephone 9266 2784
Facsimile 9266 3793
Email hrec@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Low Risk (Ethical Requirements)" for the project titled *"The effectiveness of project-based mathematics in the first year of high school in terms of learning environment, academic efficacy and achievement"*. On behalf of the Human Research Ethics Committee, I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **10th December 2012 to 9th December 2013**.

The approval number for your project is **SMEC-48-12**. Please quote this number in any future correspondence. If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.



PAULINE HOWAT
Administrator
Human Research Ethics
Science and Mathematics Education Centre

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved under Curtin University's process for lower-risk Studies (Approval Number SMEC-48-12). This process complies with the National Statement on Ethical Conduct in Human Research (Chapter 5.1.7 and Chapters 5.1.18-5.1.21).
For further information on this study contact the researchers named above or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.